

Technical Report 2007-06



Great Blue Herons in Puget Sound

Prepared in support of the Puget Sound Nearshore Partnership

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Nahkeeta Northwest



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Valued Ecosystem Components Report Series

PUGET SOUND
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The Puget Sound Nearshore Partnership (PSNP) has developed a list of valued ecosystem components (VECs). The list of VECs is meant to represent a cross-section of organisms and physical structures that occupy and interact with the physical processes found in the nearshore. The VECs will help PSNP frame the symptoms of declining Puget Sound nearshore ecosystem integrity, explain

how ecosystem processes are linked to ecosystem outputs, and describe the potential benefits of proposed actions in terms that make sense to the broader community. A series of “white papers” was developed that describes each of the VECs. Following is the list of published papers in the series. All papers are available at www.pugetsoundnearshore.org.

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Eissinger, A.M. 2007. Great Blue Herons in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Fresh, K.L. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Johannessen, J. and A. MacLennan. 2007. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

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Penttila, D. 2007. Marine Forage Fishes in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-03. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Front cover: Great Blue Heron (courtesy of Washington Sea Grant)

Back cover: Great Blue heron (courtesy of Washington Sea Grant): perched on partially submerged log, left; wading in Puget Sound, right.

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Executive Summary

The Great Blue Heron (*Ardea herodias*) is an iconic species representing the natural heritage, interconnectedness and ecological richness of Puget Sound and the greater Salish Sea (Puget Sound, Strait of Georgia and Strait of Juan de Fuca). The convergence of these marine waters with freshwater input from major rivers draining the coastal mountains, combined with over 4,000 miles of shoreline, protected embayments and extensive intertidal areas, creates an ecologically rich natural system where Great Blue Herons flourish. The temperate climate of coastal Washington and British Columbia also provides ice-free conditions for most areas and year-round foraging opportunities, resulting in a resident heron population (Butler 1992) and potentially a distinct subspecies. This area constitutes the greatest concentration of Great Blue Herons on the West Coast and harbors some of the largest heronries in North America (Eissinger 1996).

Within Puget Sound, the Great Blue Heron serves as a sentinel for nearshore function and health. As a predator and nearshore-associated species, heron populations are indicative of levels of environmental toxins, availability and connectivity of shoreline-upland habitat, and conditions of eelgrass and intertidal habitats. Feeding on a variety of prey from these upland and shoreline habitats, herons move seasonally and may concentrate in large numbers as food demands and prey abundance converge.

Great Blue Herons are colonial breeders, nesting in isolated coastal forests. The overall population of Great Blue Heron in Puget Sound appears to be stable. However, data confirm a recent consolidation of the breeding population into relatively few, large reproductive centers. With the breeding population centralized, these colonies become vulnerable to human encroachment, disturbance and increased predation. Monitoring of colony sites and productivity has become increasingly necessary with this recent trend.

The regional heron population is closely tied to marine nearshore ecosystems. Herons locate their colonies in close proximity to marine intertidal habitat, particularly eelgrass and estuaries, to maximize foraging opportunities during the nesting season. Coastal meadows, wetlands, riparian and upland forests are all utilized throughout the year for foraging, roosting, or breeding-related activities. Nutrients from nearshore prey species are transported and deposited in large quantities by herons in upland forests during the breeding season. This nutrient cycling is potentially important to the ecology of the coastal forest.

Preface: Importance of this VEC

For many Pacific Northwesterners, the Great Blue Heron is iconic. It is an animal of myth, symbol and cultural significance. The heron links people expressively from the sea and shoreline to upland meadow, marsh or pond, invoking a sense of calm, patience and solitude. For residents of Puget Sound, the Great Blue Heron represents our coastal lifestyle. It is also easily recognizable, even in silhouette, to birders and non-birders alike. Historically, herons were exploited for fashion and revered in form. The heron or 'crane' was depicted in early art, carvings and pictographs. The Nisqually Indians (according to Suckley in Jewett et al. 1953) honored the Great Blue Heron as 'our grandfather' and held a tradition that herons were transformed from men who quarreled with their wives. On the central coast of British Columbia, the Haisla and Heiltsuk people would honor Khenko, the supernatural crane or heron during the winter ceremony (Butler 1997). These ceremonies have continued for thousands of years.

In the present day, branding, marketing and commercial use of the Great Blue Heron's image has become commonplace. The Great Blue Heron as image and name is found on consumer goods, business and organization logos and music festival promotions and has even been selected as the City bird for Seattle and Portland. To celebrate, the City of Portland holds a Great Blue Heron Festival each year. The Great Blue Heron is also the subject of art in many mediums, from literature to visual to music. The economic value of the exchange of goods utilizing the heron image or name is likely substantial. The totemic value of the heron provides people with a deep, personal connection to nature and the regional lifestyle.

In natural systems, the Great Blue Heron supports ecological functions as predator and prey, colonial breeder, habitat bridge (between marine, freshwater and upland zones) and as an indicator of environmental health. With wide-spread distribution, herons utilize a variety of habitats, consuming both aquatic and terrestrial organisms. Breeding herons of

the Puget Sound nest in nearshore forests concentrated near biologically rich feeding areas, particularly marine eelgrass meadows; this habitat interface facilitates the transport of nutrients from marine to upland habitats. During nesting and reproduction, heron eggs and young fall prey to forest-associated raptors and other predators, further linking the complexity of species and habitats.

Great Blue Herons serve as indicators of environmental health within the Salish Sea. As year-round residents and top-line predators, herons consume large volumes of small prey. In so doing, they concentrate contaminants by biomagnifying locally derived toxins in their tissue and eggs, providing an excellent gauge. As indicators, they are important to the human population as part of a biological early-warning system (Wilson et al. 1996) and are referred to as a 'sentinel species' by Environment Canada (Cham-poux et al. 2002). As more persistent synthetic chemicals are found in Puget Sound and linked to deleterious effects in humans and wildlife, the use of effective nonlethal methods of tracking and measuring these compounds is increasing in importance.

From past to present, the Great Blue Heron continues to serve a sentinel role in Puget Sound as an indicator species for the coastal ecosystem, and as symbol of a regionally unique cultural lifestyle. Yet, as vast areas of landscape change and environmental stressors increase with human growth and related development, the Great Blue Heron population has also exhibited responses with colony abandonment and breeding site consolidation. Our understanding of long-term trends is lacking; however, in the past ten years, system-wide indicators emphasize the need to closely follow the heron population through consistent scientific monitoring. A comprehensive summary of data and heron-related reporting in Puget Sound is provided in this paper and is intended to reflect the current state of knowledge for this species and support the Great Blue Heron as a Valued Ecosystem Component in Puget Sound.

Background

Species and Distribution

The Great Blue Heron (*Ardea herodias*) occurs throughout North America from the Atlantic and Gulf coasts to the Pacific. The Pacific coast heron population ranges from Prince William Sound, Alaska, south through Central and South America to the Galapagos Islands (Butler 1992). The North American population consists of five recognized subspecies (Payne 1979, del Hoyo et al. 1992) including the most common or nominate form *A. herodias herodias*, which extends into western Washington state.

A non-migratory subspecies of Great Blue Heron resides in the Pacific Northwest, including the Salish Sea (i.e., Puget Sound, Strait of Georgia and Strait of Juan de Fuca) (Hancock and Kushlan 1984, Simpson 1984, Butler 1997). This resident population is described as a separate subspecies *A.h. fannini* (Payne 1979). The range of this subspecies is from Alaska to southern Washington State, with the largest concentration occurring in northwest Washington and southwest British Columbia. The type specimen for the subspecies *fannini* is from the Queen Charlotte Islands (Skidegate, Graham Island; Chapman 1901). This northwest phenotype is more melanistic or darker overall, as are many northern faunal subspecies, and they exhibit smaller bodies (Dickerman 2004).

Recently, a distinct population was suggested for the Salish Sea. Specimens from southwestern British Columbia and western Washington, including Puget Sound, show intermediate plumage coloration and size that differ from *A.h. fannini* on the Queen Charlotte Islands (north coast of British Columbia) and the Alaska panhandle, and *A.h. hyperonca* in California (Dickerson 2004). Although the subspecies *fannini* has been widely accepted as the 'northwest' form since the early 1900s, the evidence now suggests that the range of *A.h. fannini* does not extend as far south as previously assumed, but instead is confined to the most northern coastal range (Dickerman 2004). Further research is proposed to determine differences between coastal populations (Heron Working Group 2005).

The Puget Sound Great Blue Heron population is present year-round, yet its distribution is seasonally influenced and depends on foraging opportunities, weather conditions, marine water temperature and the breeding cycle (Butler 1995, Eissinger 2006). The breeding cycle has the greatest influence on distribution, with hundreds of herons converging on colony sites for about 6 months of each year to nest and raise young. During this time, large aggregations of herons may also occur at staging areas and feeding grounds. Consequently, the year is divided into two primary phases, breeding and non-breeding.

In the autumn and winter (non-breeding periods) herons are widely dispersed within the coastal and lowland areas of Puget Sound, concentrating near sea level and lower elevations. Herons are most frequently encountered as solitary birds outside the breeding season and away from breeding areas. During non-breeding periods, herons occupy foraging habitats in low densities, including shorelines of marine, estuarine and freshwater systems, and suitable upland areas, including fallow fields or margins, agricultural land and nearshore forest roosts (Eissinger 2006). Herons generally do not occupy nests or colony sites year round, although individual or small aggregations of herons may utilize colony stands or associated forest edges for roosting and loafing (Eissinger unpubl. data).

During the breeding period, large concentrations of Great Blue Heron are found locally centered around nesting colonies and associated foraging sites. The breeding period commences in January - March with the influx of adult herons to stage and breed. The conclusion of the breeding period is marked with the fledging of young from the colony and dispersal of young and adults to productive feeding grounds in July - September.

Heron colonies are distributed throughout Puget Sound (Figure 1) with larger colonies concentrated in the north Sound and southern Strait of Georgia.

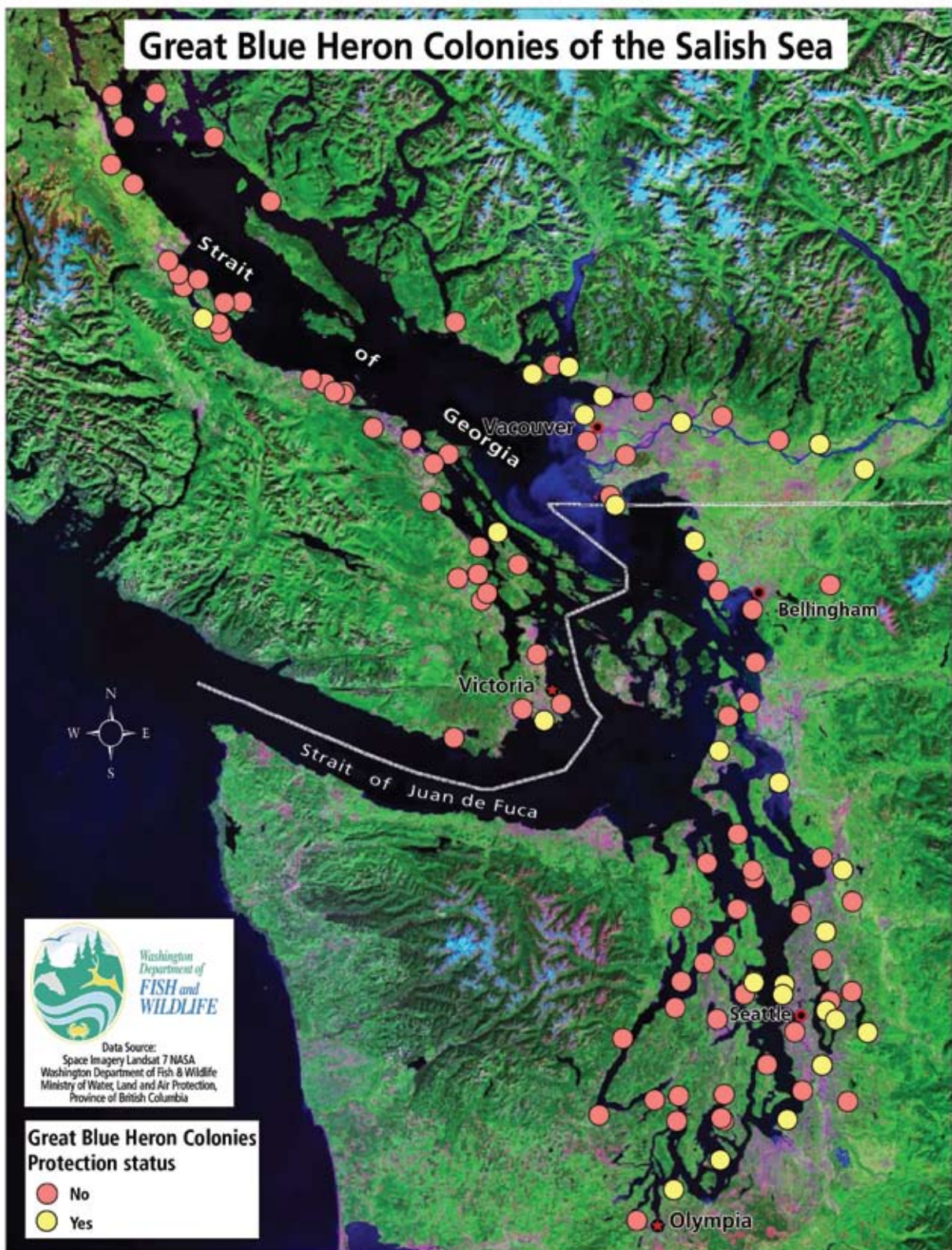


Figure 1. Salish Sea Great Blue Heron colony distribution, 2204-2005.

Life History and Habitat Associations

Physical Description

The Great Blue Heron is a familiar bird throughout the Salish Sea. It has been described in many texts, most notably in the Birds of North America (Butler 1992), Birds of British Columbia (Campbell et al. 1990) and Birds of Washington (Eissinger 2005). It is recognized by its slate-blue coloration and tall, crane-like appearance. Great Blue Herons stand well over 1 meter tall with a very long neck and legs. Their wing span is approximately 2 meters and they tuck their necks in flight, unlike cranes which fly with their necks extended. Despite their height, a heron's body is thin, weighing 2.1 to 2.5 kg (Butler 1992). Males and females vary little in appearance and are generally indistinguishable in the field. Adult herons are slate blue in color and sport a full medial white crown with black supercilium (eye brow) with associated dark head plumes. Adult plumage also includes dark shoulder patches and body plumes. Juvenile herons appear dull gray overall and lack both the white crown and plumes of the adult.

Breeding

The Great Blue Heron is the largest colonial nesting bird in the Pacific Northwest. Nesting areas are referred to as heronries or nesting colonies. Heron colonies range from fewer than five nests to more than 500. Occasionally, herons will nest as solitary pairs. Small nesting colonies are sometimes referred to as satellite colonies and may constitute a relocation attempt, new colony formation, fragmentation of a larger colony, or limited local carrying capacity. Large colonies with 200 or more nests have been referred to as mega-colonies to distinguish them as particularly large concentrations.

Colony sites are selected by breeding adults for suitable nesting substrate, isolation and proximity to prey-rich feeding areas (Simpson 1984, Butler 1995). Great Blue Heron breeding colonies are usually located in close proximity to their primary feeding grounds (Gibbs et al. 1987) and average 2.3 km from these areas (Butler 1991) and as far away as 12 km (Birch Bay and Post Point) (Eissinger unpubl. data). Ecologically rich eelgrass meadows of shallow coastal embayments are the primary feeding areas for breeding herons along the coast (Butler 1991).

Heron colonies are located in nearshore forest stands comprised of mature trees that are large and structurally suitable to hold stick nests up to a meter wide and one-half meter deep. An adequate supply of nest material is also important; both deciduous and conifer twigs are utilized. Each nest is built and then reused annually, with nest material individually woven into the nest structure (Gibbs et al. 1987). Historically, up to 32 nests have been documented in a single tree (Kelsall 1992), although typically, trees contain 1 to 5 nests. However, in well established colonies, large big-

leaf maple, cottonwood and alder have been recorded with 10-17 nests (Point Roberts and Samish Island) (Eissinger unpubl. data).

Hérons have been documented nesting in at least 18 tree species in Washington, including 8 deciduous, 9 coniferous and one broad-leaved evergreen. Puget Sound tree species most commonly include grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera*), big-leaf maple (*Acer macrophyllum*) and Pacific paper birch (*Betula papyrifera*). Less commonly used are western hemlock (*Tsuga heterophylla*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*), willow (*Salix* sp.) and quaking aspen (*Populus tremuloides*) (Eissinger unpubl. data). Herons rarely use human structures; however, there are two accounts of herons nesting on power transmission towers in association with nesting ospreys and one account of nesting on pilings at a ferry dock. Herons utilize habitats from urban sites to wilderness. Most colonies are located in buffered forest stands separated from human disturbance (Thompson 1977, Gibbs et al. 1987).

It was once assumed that heron colonies within a forest stand were static; however, long-term mapping of colonies has proven that nesting areas within the stand move and may shift dramatically in a single year (Eissinger 2005). A forest stand that provides adequate buffer protection and area for a heron colony to move or expand may improve site fidelity, longevity and productivity of the colony over time.

The breeding season for Pacific Northwest coast herons extends over a 6-month period and consists of six phases, from staging and reoccupancy of the colony to fledging of young and dispersal. The onset of breeding and nesting is positively correlated to latitude and seasonal temperature of marine waters (Butler 1997). Photoperiod, weather and food availability are also influential factors (Gill 1990, Butler 1993). In Puget Sound, colonies in the South Sound breed earlier and in smaller concentrations than those of the North Sound and southern Strait of Georgia, which nest later and in larger concentrations.

Breeding begins during January or February in the south and central Puget Sound, and February or March in northern regions. The season commences with the gathering and staging of mature males in an area near the heronry, followed by movement into the colony. Staging has been documented in both natural habitat and human structures. The arrival of females to the heronry prompts a period of mate selection and elaborate courtship activity. Courtship and pair bonding involve 14 behavioral displays and vocalizations (Mock 1976). Nest repair and construction is a shared responsibility and includes ritualistic elements between the male and female herons in a breeding pair. The period of

early courtship and bonding has been described as the most sensitive period for the colony due to the herons' extreme response to disturbance and potential to abandon their nest. As eggs are laid and incubation ensues, it is thought that the bond to the nest increases and, although still easily disturbed, the pair becomes increasingly tolerant. Egg laying occurs over a period of a week or two, but varies within each heronry, resulting in asynchronous hatching. Brooding is brief and adult attendance at the nest is maintained for

the first 3 to 4 weeks, depending on weather conditions and threat of predation. In the event a clutch of eggs or brood is lost, the pair may make a second nesting attempt, which extends the nesting period. Rearing of young requires 8 weeks until they fledge from the nest. The breeding season concludes when all juveniles and adults have dispersed from the colony. Timing can range from June to early September depending on the location and incidence of second broods. Reproductive chronology is summarized in Table 1.

Table 1. Northwest Washington Great Blue Heron breeding chronology (from Butler 1989, Eissinger unpubl. rep.).

February-March	March-April	April	May	June-July	July-August
variable period	variable	28 days	28 days	28 days	variable
pre-breeding staging & colony reoccupation	nest building, mate selection, courtship	egg laying and incubation	hatching and brooding, rearing	rearing large active young	fledging and dispersal from colony

Heron productivity is variable by location and year. It is likely dependent on prey abundance, weather, predation, human disturbance and adult fitness. Herons lay one clutch of four to five eggs. Productivity is measured by the number of fledged young per nest attempt and generally ranges from one to three, although occasionally four and rarely five will fledge. Most of the variation in nesting success is attributable to nesting failures. Productivity at individual colonies varies. At the southern reach of the Strait of Georgia, it ranges from a mean 1.7 young per successful nest at Birch Bay to 3.0 at Point Roberts (Gebauer 1993, Eissinger 2004), whereas mean fledging success for combined colonies in the Strait of Georgia is 1.7 (Butler et al. 1995). Productivity in central and south Puget Sound has not been well studied. Data from 2001 in King County estimated a mean of 2.0 - 3.0 fledglings per nest (Stenberg 2001). Loss or reduction in productivity was identified as a limiting factor in British Columbia heron populations (Vennesland and Butler 2004). Causes of reduced colony productivity throughout the Salish Sea include bald eagle incursions and predation, human disturbance, food limitation, weather and unexplained abandonment (Butler et al. 1995, Eissinger 2000, Gebauer and Moul 2001, Vennesland and Butler 2004).

Feeding

The Great Blue Heron has been described as 'the patient predator' (Butler 1995). It feeds on fish, invertebrates, small mammals and occasionally amphibians and reptiles. As a predator on land and in water, the heron requires specific adaptations. Its characteristic kinked neck and articulating vertebra enable it to thrust its head and beak quickly and accurately with each strike. The long legs give it the ability to wade in deeper water than any other North American wading bird. The heron's plumage color blends with the

grey-blue of the water and sky interface, acting as a camouflage. The eyes are situated to allow bifocal vision with a wide field of view, and a high number of rods enable good vision in low light and at night.

The hunting behavior of herons is slow and deliberate. By situating themselves in areas of abundant prey, herons are able to stand and wait for their quarry. On average, adult herons make 100 strikes per day while fishing, with a capture rate of approximately one fish every 2 minutes (Butler 1995). Juvenile herons, however, have a capture rate of fish about 50 percent less than that of adults, which forces them to hunt the slower, larger prey such as field voles and mice (Butler 1995). Seasonal changes cause a shifting of prey availability and influence heron foraging patterns, territoriality and distribution.

Great Blue Heron foraging concentrations and habitat associations are not well documented. Foraging surveys within the Puget Sound have been conducted sporadically and most provide single-day data collected during the breeding season. Ground and shoreline surveys include one year-long study (Eissinger 2006) and periodic sampling (Eissinger 1998 - 2006 unpubl. data). Two major aerial studies enumerated heron aggregations along specific transects. These studies include the 'Big Sit', a volunteer-based survey from Everett to Point Roberts Washington, June 2001 (Norman 2001), and the Washington Department of Fish and Wildlife (WDFW) Puget Sound - Hood Canal heron foraging study, from Olympia north to the U.S./Canada boundary, June 2004 (G. Hayes, WDFW, Olympia, Washington, unpubl. rep.). Both the 2001 and 2004 aerial surveys involved single-day flights combined with a multi-day ground survey component. The results of the two studies were mapped and indicate important heron nearshore habitat associations, particularly large aggregations near breeding sites (Figure 2).

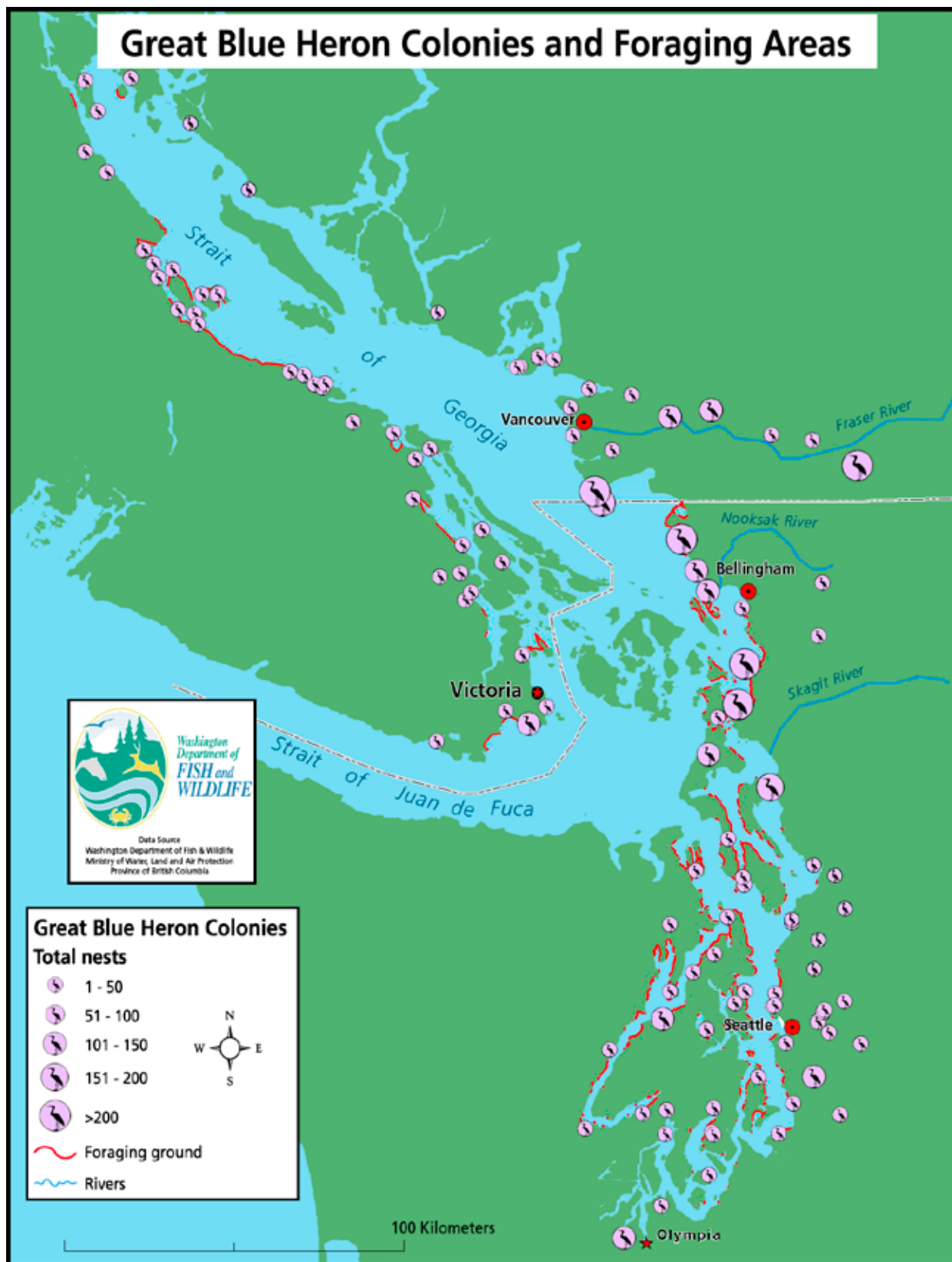


Figure 2. Salish Sea heron foraging areas and colonies, 2003-2004.

Foraging Habitat and Prey

Great Blue Herons utilize a matrix of habitat types depending on local conditions, tides and season. Foraging habitats include marine, freshwater and upland areas. Herons are primarily associated with aquatic systems statewide, including ponds, lakes, marshes, streams, ditches, rivers, sloughs, estuaries, intertidal areas, eelgrass meadows and shoreline riparian areas. Marine foraging areas are vital to the successful reproduction of coastal Great Blue Herons. Upland foraging is also important and is concentrated in meadows, fallow fields and grassy margins along roadways and ditches. The proximity of prime foraging areas is central to breeding colony locations and is linked to their productivity.

The diet of herons in marine areas is dictated by prey fluctuations related to life cycle, season and location. Simpson (1984) demonstrated that the herons' rate of prey capture increased significantly between April and June, during which time prey abundance also increased in the feeding area. Herons captured more prey on the ebb tide and in deeper water, above the heron's knee. Sea water temperature was also a factor determining heron foraging success and prey abundance in intertidal eelgrass areas (Butler 1997).

The prey species upon which the heron feed have been recorded in only a few locations in the Strait of Georgia. No comprehensive study of the heron's marine prey species has been made in Puget Sound. The heron's diet is seasonally influenced. Table 2 lists the prey species found during the whole year. However, during the breeding season, targeted prey in the Strait of Georgia are more limited, consisting of seven primary fish species, all of which are associated with eelgrass meadows: saddleback gunnel, crescent gunnel, Pacific staghorn sculpin, tidepool sculpin, shiner perch, threespine stickleback, bay pipefish, starry flounder, plainfin midshipman and walleye pollock (Forbes et al. 1985, Butler 1995).

Saltwater and freshwater marshes provide year-round foraging opportunities. Specific prey items and seasonal fluctuations in abundance are little known; however, fish, crustaceans, amphibians, reptiles and small mammals are found in these areas (Table 2). Inland marshes, forested wetlands and stream courses typically offer shoreline foraging, protection from adverse conditions, and roost sites along the riparian perimeter.

Terrestrial habitats offer another year-round foraging area. Contrary to the popular image of the heron as a shoreline stalker, inland fields, grassy edges and ditches are important and common hunting sites for a variety of prey items (Table 2). They provide optimal habitat for small mammals, one of the most important components of the Great Blue Heron diet, particularly field voles (*Microtus townsendii*). Small mammals sought by herons during the breeding season in certain inland areas can make up 40 percent of the nestlings' diet. In the northwest, the major heron colonies are located near open agricultural areas with fallow fields, wet meadows

Table 2. Great Blue Heron prey species (from Forbes et al. 1985; Butler 1995, 1997; Eissinger unpubl. data)

Terrestrial

Pacific treefrog	<i>Hyla regilla</i>
Townsend's vole*	<i>Microtus townsendii</i>
Vagrant shrew	<i>Sorex vagrans</i>
Snakes	Various species

Freshwater

Bullfrogs	<i>Rana catesbeiana</i>
Crayfish	<i>Pacifastacus leniusculus</i>
Peamouth chub	<i>Mylocheilus caurinus</i>
Redside shiner	<i>Richardsonius balteatus</i>
Threespined stickleback	<i>Gasterosteus aculeatus</i>
Cutthroat trout	<i>Oncorhynchus clarki</i>
Rainbow trout	<i>Oncorhynchus mykiss</i>
Salmon	<i>Oncorhynchus</i> sp.

Marine

Bay pipefish	<i>Syngnathus leptorhynchus</i>
Crabs	Various species
Eulachon	<i>Thaleichthys pacificus</i>
Crescent gunnel*	<i>Pholis laeta</i>
Saddleback gunnel*	<i>Pholis ornata</i>
Isopods	<i>Idotea</i> sp.
Mud shrimp	<i>Upogebia pugettensis</i>
Pacific herring	<i>Clupea harengus pallasi</i>
Plainfin midshipman	<i>Porichthys notatus</i>
Sculpins*	Various species
Shiner perch*	<i>Cymatogaster aggregata</i>
Staghorn sculpin*	<i>Leptocottus armatus</i>
Starry flounder	<i>Platichthys stellatus</i>
Surf smelt	<i>Hypomesus pretiosus</i>
Threespined stickleback	<i>Gasterosteus aculeatus</i>
Tube-snout	<i>Aulorhynchus flavid</i>
Walleye pollock	<i>Theragra chalcogramma</i>
Salmon	<i>Oncorhynchus</i> sp.

*Primary prey species

and ditch edges in which herons hunt. Juvenile herons, in particular, depend on small mammals as a primary food source during the winter months as a result of their inefficient fishing abilities (Butler 1995). Adults also shift to fields from November to February, when marine intertidal opportunities are limited by high daytime tides (Butler 1995).

Nutrient transport by herons from marine foraging areas to the upland is an ecological function with little documentation. Herons consume an estimated 300 g of fish daily (Butler 1995) and are estimated to assimilate 75-80 percent of the energy from their diet. They then excrete nutrient-rich byproducts. Within the 10 largest heron colonies, 400 to 1,200 adults plus an average of 2 young per nest will defecate within the nesting area and associated upland forest over 5 months every year. The actual nutrient loads deposited and the effects on the forest vegetation and soils have not been measured within the Pacific Northwest. This is a seasonal transfer of nutrients from primary feeding grounds, particularly marine intertidal areas, to the upland forest. The nutrients include marine-derived nitrogen, which has been identified as being beneficial to tree growth rates and optimizing riparian forest health (Helfield and Naiman 2002).

Roosting

Great Blue Heron rest periodically both at night and during the day at locations known as roosts. Roosting activity and related habitat has not been described in Puget Sound; however, roosts have been identified in many areas (Eissinger unpubl. data). In British Columbia, roosts were described briefly (Gebauer and Moul 2001). Selection of roosting sites depends on season, time of day and weather conditions. Diurnal roosting may occur in groups and is thought to be a social behavior in some instances. Diurnal roosts are close to nesting colonies during the breeding season and, in many cases, situated in mature conifers, along marine shorelines, bluffs, jetties, or openings providing direct sun exposure. These areas are used for sleeping, loafing, preening and sunbathing. Open salt-marsh flats and fields are other diurnal roost locales, usually identified with the presence of several individuals, typically females and immature herons. Many diurnal roosts near colony sites are also utilized as staging areas prior to the nesting season. Nocturnal roosts are likely situated in nearshore forest stands, but their locations and characteristics have not been studied. Roosting sites should be identified and mapped as an integral part of the species' primary habitat.

Wintering

As a non-migratory subspecies (Butler 1991), the northwestern Great Blue Heron is resident year-round. Winter survival requires energy conservation, efficient hunting skills, access to ice-free foraging areas including fallow fields and the presence of protected roosting sites. Adult herons, primarily males, maintain shoreline territories during the winter months (Butler 1995). Females and juveniles can be more

loosely associated, mingling in small aggregations while foraging, roosting and loafing. The small mammal component of the heron's diet is vital during the winter months, particularly for juvenile survival.

Mortality

Mortality of Great Blue Herons in the northwest has numerous causes and is a limiting factor for the regional heron population (Butler 1997, Gebauer and Moul 2001). Major causes of mortality range from predation of eggs, young and adults to accident-related injuries and starvation. Egg and nestling mortality is generally the result of bald eagle (*Haliaeetus leucocephalus*) predation, and less frequently, scavenging of unattended nests by crows (*Corvus caurinus*) or ravens (*Corvus corax*) (Simpson 1984, Kelsall 1992, Butler 1995). Siblicide is also a factor in nestling mortality (Butler 1997). The survival to fledging per egg laid averages 53 percent; for juvenile birds the survival rate is approximately 27 percent and adults 73 percent (Butler 1995). Although the shooting of herons is illegal in both the United States and Canada, it is reported that 5 percent of herons brought to wildlife rescue facilities were shot. In addition, entire colonies have failed when exposed by logging and subsequently shot from access roads (WDFW database [see Data Sources]). Unexplained mass abandonment of young from nests and mid-season colony failures are also documented causes of mortality (Eissinger unpubl.). Collision with human-made structures or vehicles is a likely cause of broken bones and lacerations, leading to death. Other causes include poisoning, entanglement in fishing gear, parasites, fish caught in the gullet and predation (Butler 1995).

Bald eagles are the primary predator of heron eggs, nestlings, juveniles and less frequently adults (Norman et al. 1989, Vermeer et al. 1989, Butler 1995) and are the cause of nest failure in some colonies (Simpson 1984; G. R. Venesland, British Columbia Ministry of Water, Land and Air Protection, Surrey, unpubl. rep.). Bald eagle predation in heronries has become common due to the growing density of eagles and nest territories in coastal areas. Most large heronries have active eagle nests within or adjacent to them. It is assumed, based on eagle behavior, that adult eagles defending their territories protect the herons from a host of other predators. However, the territorial eagle pair and their offspring will hunt within the colony. It is thought that the attacks on adult herons cause the greatest disturbance to the colony and may be cause for abandonment. Another factor in the eagle - heron relationship is the substantial increase in the bald eagle population over the past 20 years, with 10 percent annual growth in the population (Stinson et al. 2001). This growth trend has been documented statewide for nearly 20 years with the number of nesting pairs increasing from 105 in 1980 to 550 in 1995 to 664 in 1998 (Stinson et al. 2001). Continued pressure by bald eagles on heron productivity and colony stability is predicted.

Nearshore Habitat Requirements

The nearshore habitat requirements for Great Blue Heron include a matrix of habitat types, each with spatial and temporal significance to heron survival and reproduction. In Puget Sound, these include:

1. **Marine Shoreline and Intertidal:** protected embayments, shoals, eelgrass, salt marsh
2. **Estuaries:** stream and river outfall and delta
3. **Freshwater Systems:** wetlands, marshes, streams, ponds, lakes, rivers
4. **Coastal Forests:** riparian forest, nearshore upland forest
5. **Upland Field:** coastal meadow, fallow field, agricultural field, ditches and dikes.

The interplay between these habitats is less well studied but appears to be vital in the heron life cycle. In the coastal regions, close proximity and connectivity of these habitats with the nearshore creates a landscape linkage. In addition, the connection of these habitats is also tied to the herons' use either seasonally or daily, reflecting tides and weather patterns.

Marine Shoreline and Intertidal

Marine shoreline habitats are important year-round use areas for Great Blue Heron and are vital to the successful productivity of coastal heron colonies. As a wading bird, herons seek relatively shallow and low-gradient intertidal areas in which to forage, selecting sites to maximize their foraging time and effort (Simpson 1984, Butler 1995, Norman 2001; Eissinger unpubl. data; G. Hayes, WDFW, Olympia, Washington, unpubl. data). Intertidal areas with eelgrass (*Zostera marina*) habitat are favored.

Eelgrass is a vascular plant that grows in shallow marine embayments and creates dense cover utilized by numerous fish species and crustaceans for spawning, rearing and protection from predators. Simpson (1984) showed that feeding success in eelgrass is greater than in other intertidal areas with a variety of bottom substrates in the British Columbian Gulf Islands. However, mud, gravel or rocky substrates, shellfish beds and saltmarsh habitats are also utilized (Simpson 1984). Puget Sound Great Blue Heron foraging habitat, distribution and concentration areas were documented by a WDFW aerial survey in June 2004 and illustrated on maps from Drayton Harbor to the south Sound and Hood Canal (Appendix A) (Hayes 2006).

Eelgrass occurs throughout Puget Sound and Hood Canal. Eelgrass area is limited in the south Sound compared to the greater concentrations and contiguous areas found in the north. According to the Washington State Shore Zone Inventory (Washington Department of Natural Resources [WDNR] 2000), eelgrass beds (*Z. marina* and *Z. japonica*) occur along 37 percent of shorelines (3,000 miles in Puget Sound). Data examined for both Puget Sound and southern Strait of Georgia show a positive link between coastal heron colony location and size with intertidal eelgrass (*Z. marina*) habitat (Table 3). The growth of the Point Roberts heron colony over 20 years and the colony's primary feeding area at Roberts Bank is illustrative. The construction of jetties on Roberts Bank in 1960 created a sediment trap near the mouth of the Fraser River, resulting in the expansion of the associated eelgrass beds at a rate of about 5.4 hectares per year; during the same period, the nearby heron colony grew on average by 10 pairs per year, reaching a high of 474 in 1995 (Butler 1997).

Table 3. Heron colony–eelgrass association, Strait of Georgia to Puget Sound.

Heron Colony	Colony Size (#nests) - year	Primary Feeding Area(s)	Distance from Colony	Eelgrass Area
Point Roberts	400 - 2003	Roberts Bank	4 km	410 ha 1
Birch Bay	274 - 2004	Drayton Harbor	8 km	291 ha4
Birch Bay	274 - 2004	Birch Bay	1+ km	481 ha4
Slater Road	150 - 2004	Lummi Bay	<1 km	630 ha2
Samish Island	220 - 2004	Samish Bay	<1 km	1950 ha2
March Point	600 - 2004	Padilla Bay	<1 km	3800 ha2
Davis Slough	184 - 2004	Skagit Bay	1+ km	2795 ha3
Nisqually	27 - 2000	Nisqually Delta	<1 km	25 ha2

Data Sources:

1 The Great Blue Heron (Butler, 1997)

2 Puget Sound Submerged Vegetation Monitoring Project 2003-2004 Monitoring Report (Dowty et al. 2005).

3 Skagit River System Cooperative 2006

4 Whatcom County Critical Areas Maps 2004 Update

The Puget Sound Submerged Vegetation Monitoring Project 2003 - 2004 Monitoring Report (Dowty et al. 2005) notes that '*Zostera marina* in Puget Sound is highly aggregated with more than a quarter of the total (27%) located in Padilla and Samish Bays.' This same area supports about 1,640 breeding Great Blue Herons annually, representing about 53 percent of the Puget Sound breeding population based on 2004 colony counts (Cunningham, Skagit Land Trust, Mt. Vernon, Washington, and Eissinger unpubl. data). Padilla Bay has the largest eelgrass area in the Puget Sound¹ and the largest on the west coast south of Alaska (Dowty et al. 2005). This expansive eelgrass complex supports the largest Great Blue Heron colony in the Salish Sea.

Currently, it is estimated that 73 percent of the active heron colonies in the Puget Sound are directly associated with marine and estuarine intertidal habitats for foraging activities during the breeding season. Of these colonies, nearly all have a direct association with eelgrass habitat and the reproductive success of these colonies is likely dependent on prey associated with eelgrass. With the expansion of the introduced *Z. japonica* within many embayments, it is possible that foraging opportunities for Great Blue Heron will increase with the associated expansion of prey into those areas. This assumption needs further study. To date no studies have been conducted to investigate the effects of *Z. japonica* expansion either in spatial or ecological terms (D. Bulthuis, Padilla Bay National Estuarine Research Reserve, pers. comm.).

Heron utilization of marine shoreline areas also includes upper intertidal habitat, estuaries, shoreline perches and riparian forest. During diurnal high-tide periods, herons seek foraging opportunities in the upper reaches of the intertidal zone or follow freshwater systems to favorable foraging sites. Large woody debris, boulders and floating rafts all serve as platforms for individual herons foraging at high tide. Individual herons also utilize subtidal areas by perching on floating docks, kelp (*Nereocystis luetkeana*), or other natural or human-created platforms. Areas of undeveloped shoreline offer greater shoreline habitat complexity and less human disturbance for foraging herons.

Estuaries

Estuaries, both small and large, provide complex habitats with high nutrient influx and abundant prey for herons. River estuaries and associated deltas — such as the Fraser, Nooksack, Samish, Skagit, Stillaguamish, Snohomish, Skykomish, Hamma Hamma and Nisqually — all support heron breeding populations. Lowland stream estuaries also serve an important role in heron foraging. Estuarine areas function as year-round habitat for a variety of uses including staging, loafing and dispersal of young. These areas experience large concentrations during seasonal foraging,

¹ Bulthuis, D. A., and S. Shull. Eelgrass distribution in Padilla Bay, Washington in 2000: gains and losses over a decade. Presentation at the Pacific Estuarine Research Society, April 3-4, 2003, Vancouver, Canada.

which may coincide with breeding and migration of anadromous fish species.

Upland Coastal Forest

Upland habitat directly associated with the nearshore includes coastal forests as the primary nesting area for Great Blue Herons in the Puget Sound. Of the 59 colonies active in 2003-2004, at least 43 colonies or 73 percent are located within 2 km of the marine shoreline, with many of the nest stands creating shoreline - upland links. As colonial nesters, herons nest in high density within forest stands, yet require contiguous forest area for intra-stand movement and protective buffering from weather, predators and human-related disturbance (Eissinger 2005). Herons also use forest edges, particularly shoreline/riparian forest, and small groves or individual large trees with lateral branches or flat tops for perching, preening, sunbathing, staging, roosting, loafing, and both fledging and dispersal of young.

Upland Field

The heron's upland - nearshore habitat connection is linked to seasonal use patterns, prey availability and environmental factors. Two studies tracked heron use of uplands, breeding sites and marine foraging areas over one year on the Fraser River Delta (Butler 1995) and Birch Bay (Eissinger 2006) (Figure 3a and 3b).

Both studies show that heron use uplands year round, but the seasonal pattern of use varied substantially between sites. The reduced use of upland during the breeding season at the Fraser River site is closely related to a greater distance between the upland fields and the nearest colony. During April through August, marine water temperatures increased, resulting in increased prey abundance, causing heron to move into the intertidal areas closer to the colony to forage. The Birch Bay site was situated adjacent to a major colony and reflects greater upland field use during this same period. The largest aggregations of herons outside the colony were documented during pre-breeding staging in fields adjacent to the colony in March, and foraging in marine intertidal areas in July and August. A significant fallow field habitat association was also documented, representing 63 percent of upland habitat use by herons outside the nest stand.

Both studies documented regular heron movement between intertidal areas and upland habitat. Heron flight data collected at two large colonies indicate that flyways connecting nearshore and upland habitats facilitate the success of a coastal heron colony (Eissinger unpubl. data). The link between the nearshore and upland habitats also serves a variety of other avian species for which the heron is representative (Eissinger 2006). Numerous waterfowl, shorebirds, raptors and passerines move between the nearshore and upland on a seasonal basis (Eissinger 2006).

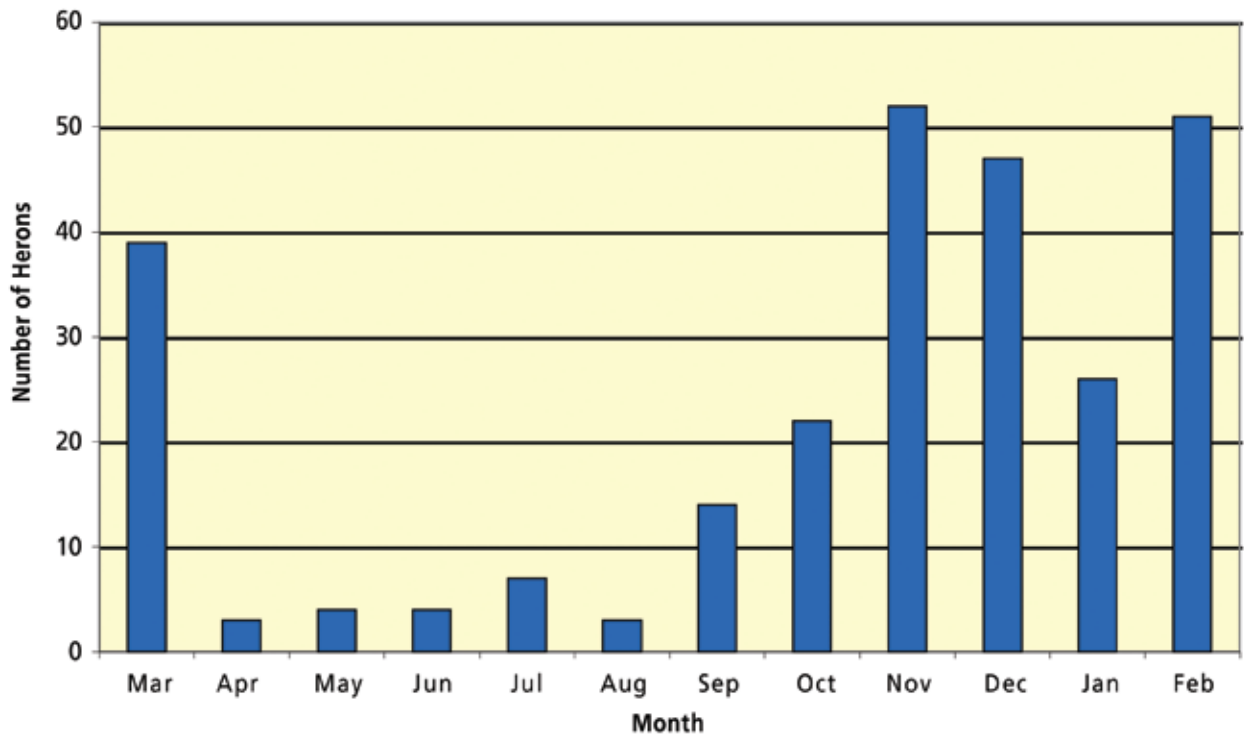


Figure 3a. Monthly upland heron abundance in Fraser River Delta (Butler 1995).

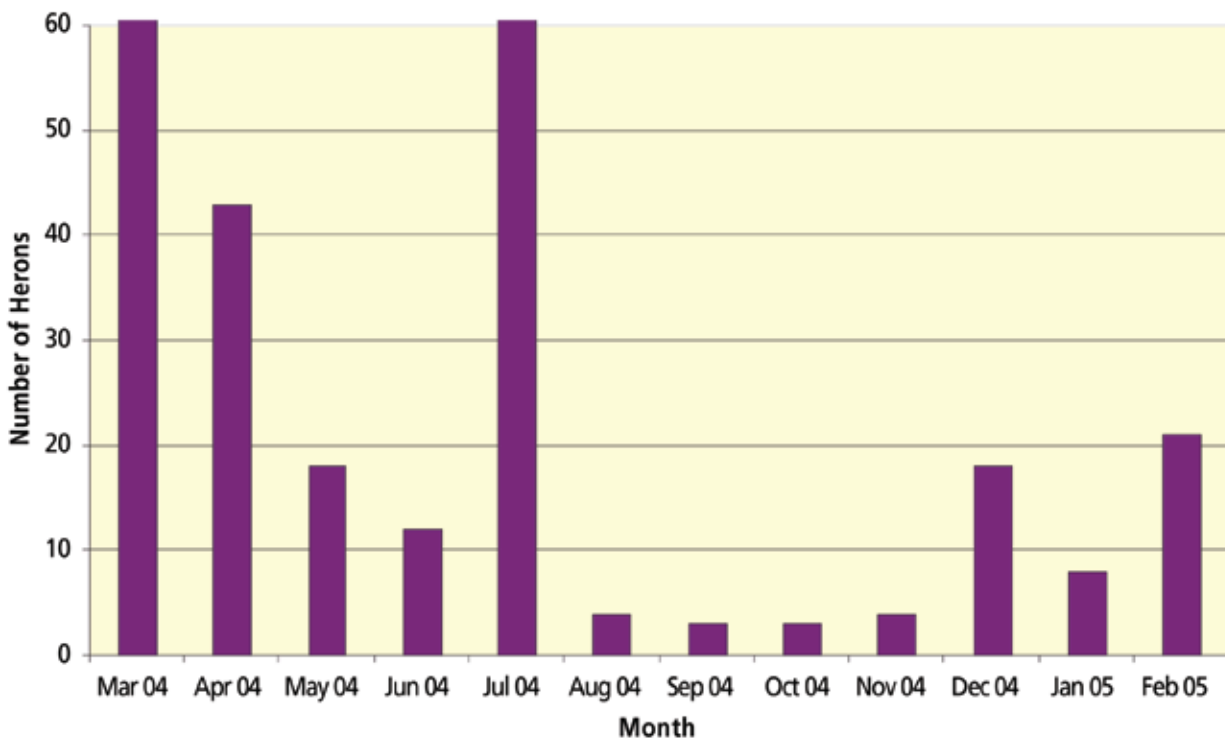


Figure 3b. Monthly upland heron abundance in Birch Bay (Eissinger 2006).

Status and Trends

Great Blue Heron populations are influenced by changing environmental conditions throughout the Pacific Northwest. Their status and distribution reflect these changes as the regional human population has expanded over the past century. As with many wildlife species, few records of historical trends exist for the heron's western range. Shoreline and associated upland development, resulting in the removal and alteration of suitable nesting and foraging habitat, had the greatest historical influence on herons in this region.

Status reports for regional Great Blue Heron populations include Puget Sound (Norman 1995), Strait of Georgia (Butler 1989; Moul 1998a, b; Gebauer 1993; G. R. Vennesland, British Columbia Ministry of Water, Land and Air Protection, Surrey, unpubl. rep.), Salish Sea (Eissinger 1996, Eissinger 2005), Washington State (Eissinger 2005) and British Columbia (Campbell et al. 1990, Gebauer and Moul 2001), as well as specific geographical areas such as King County (Murphy 1988, Stenberg 2001) and Whatcom County (Eissinger 1994). These accounts vary in objective, level of detail and data collection methodology.

Methods for monitoring heron colonies and estimating regional populations have evolved. In southwest British Columbia, complete inventories of all known colonies using specified methods are conducted in a single season. In western Washington, colony status has been updated approximately every four years by State Regional Biologists, while larger colonies in certain areas are monitored annually by independent biologists or conservation groups. In both regions, heron colonies are determined to be either active or inactive, and in most cases the number of nests is used as a measure of colony size and breeding activity. Standard monitoring methods and frequency have yet to be adopted or applied uniformly within the Salish Sea.

Salish Sea Population and Distribution

The regional heron population includes both Washington and British Columbia and, therefore, needs to be reviewed from a transboundary perspective. In 1996, Butler estimated the entire breeding population of northwestern Great Blue Heron at 4,000 pairs or 8,000 individual herons, with most of this total concentrated within Puget Sound and the Strait of Georgia. More recently, in 2005, a review of breeding data and active colonies throughout the Salish Sea was conducted in cooperation with the Canadian Wildlife Service, the Province of British Columbia and WDFW (Eissinger 2005). A total of 121 active heron colonies were reported between 2003 and 2004, representing 4,700 nesting pairs or 9,400 breeding herons (Figure 4).

Heron Breeding Population Distribution 2004

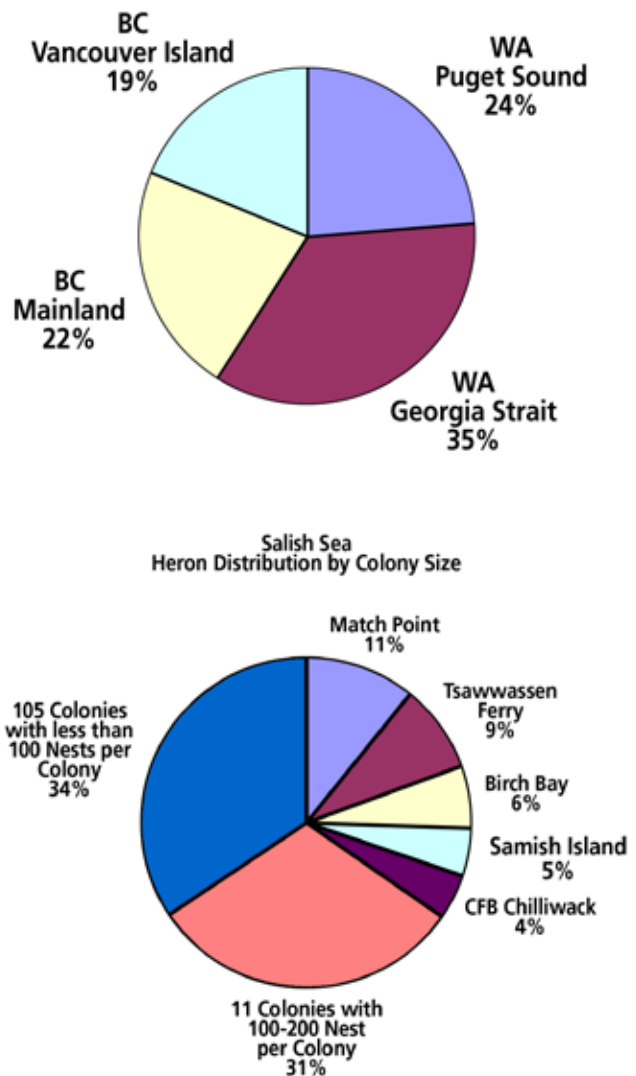


Figure 4. Salish Sea Great Blue Heron colony distribution.

Of the combined Salish Sea heron breeding population, the distribution was broken down into four geographic areas containing roughly equal proportions of the population (Figure 4). Of the 121 colonies representing 4,700 nesting pairs, the breeding population is divided almost evenly into three colony size classes (Figure 4, lower panel). Currently, 66 percent of the population is concentrated in only 16 colonies. It is important to note that 35 percent of the breeding population is concentrated in only five mega-colonies supporting 200 - 600 breeding pairs each. These large colonies constitute the nucleus of the Northwest's resident heron population and are critical for its sustainability.

British Columbia

British Columbia's Strait of Georgia, Vancouver Island and the mainland Sunshine Coast offer differing habitat opportunities and breeding concentrations. Within the inland waters of British Columbia, 62 active colonies with 1,919 nesting pairs were recently recorded (Eissinger 2005). Trends in British Columbia include coastal heron population declines between 1966 and 1994 based on breeding bird survey results (Downes and Collins 1996). Observations indicate that fewer herons now breed on the Sunshine Coast, although they were numerous in the 1980s. Causes of decline were identified as human-related disturbance, habitat loss and bald eagle predation (Butler 1996). Further analysis of the historical database, combined with more recent data, revealed that the number of Great Blue Herons joining and leaving colonies in south-coastal British Columbia remained relatively stable from 1986 to 2001 (G. R. Vennesland, British Columbia Ministry of Water, Land and Air Protection, Surrey, unpubl. rep.). Vennesland also reported that contrary to the notable nesting success from 1987 to 2001, productivity declined significantly over the same period, indicating a potential for a future population decline resulting from reductions in recruitment to breeding colonies.

Washington State

The first complete review of western Washington's Great Blue Heron population data (Eissinger 1996) provided breeding population estimates by county. Based on the best available data, the combined total was 101 active colonies with 2,356 pairs. At that time, colonies were not surveyed annually and certain sites were recorded as active but no nest numbers were provided. In 2001, a review of 342 colony records from the WDFW database was made (Eissinger 2005). Based on these records, the statewide Great Blue Heron breeding population of 6,300 pairs was extrapolated from the most recent number of nests or nesting pairs recorded at each active colony between 1990 and 2001. By the year 2000, systematic survey efforts were increased for Puget Sound, providing more reliable data. Within Washington state, the greatest breeding concentration occurs within the Puget Sound/Strait of Georgia with 3,027 nesting pairs in 114 colonies, followed by the upper Columbia River/Eastern Washington with 1,588 pairs in 78 colonies, the lower Columbia with 1,340 pairs in 26 colonies and the Olympic Peninsula/West Coast with 348 pairs in 22 colonies. However, of these, 105 colonies had not been surveyed in the past 5 years and at least 28 had become inactive or abandoned within the 11-year period.

The colony abandonments on record were due to logging, two colonies were shot and the largest colony in the south sound was completely destroyed (and others were damaged) during the 1996 ice storm. In 1999, significant abandonment was reported throughout western Washington including the largest colony at the time, Birch Bay with 440 nests, plus other smaller colonies (Eissinger 2000, Stenberg 2001). Fortunately, many colonies reestablished the following year (2000); however, colony abandonment and failure have continued.

Puget Sound

The most recent (2003 - 2004) review of heron data for Washington's Puget Sound and southern Strait of Georgia found a total of 59 active heron colonies representing 3,064 nesting pairs. This includes 49 colonies in Puget Sound with 1,114 nesting pairs, and 10 colonies in the Strait of Georgia with 1,951 nesting pairs (Eissinger 2005).

Great Blue Heron breeding populations throughout the Salish Sea have redistributed into larger colonies and have become more concentrated, particularly within Washington's inland marine area. The Puget Sound population has drastically redistributed in less than 10 years. Of the region's 59 colonies, 10 are located in association with the Strait of Georgia and represent 59 percent of western Washington's breeding population; in contrast, 40 colonies with 30 percent of the breeding population are situated in Puget Sound (Figure 5). Within Puget Sound, four colonies representing 4 percent of the breeding population are inland and lack direct association with the nearshore. Hood Canal represents five colonies with 7 percent of the breeding population. Hood Canal and the south Puget Sound represent the lowest breeding density.

Western Washington Breeding Heron Distribution

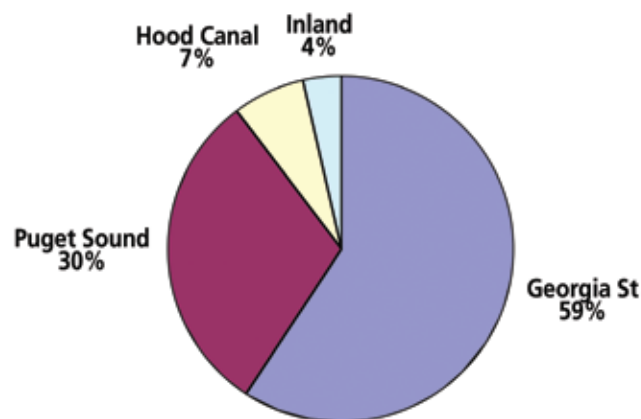


Figure 5. Puget Sound Regional Distribution.

In an effort to estimate changes in population, colony data based on nest records were compared using three data-sets over a 10-year period. Based on the available data records provided by the WDFW, supplemented by biologists' records, between 1995 and 2000 the Puget Sound heron breeding population increased 28 percent and then remained stable for the next 5 years. The change between 1995 and 2000 was likely influenced by the increased monitoring effort in 2000, particularly considering the declines in certain colonies following mass abandonment in 1999. Although the data indicate a 28 percent population increase between 1995 and 2000, the number of colonies only increased by 13 percent; by comparison, between 2000 and 2004 with the population holding steady, the number of colonies dropped by 48 percent (Figure 6).

Further examination of this change breaks down the total number of colonies by size (Figure 7) and shows a significant shift. In 1995 the majority of the breeding population (59%) was diffusely distributed across the landscape in 97 small colonies (<100 nests). Within 5 years a shift was evidenced by nearly 10 percent of the breeding population moving from small colonies into fewer large colonies. By 2004, 80 percent of the heron breeding population had consolidated into 11 large colonies, leaving only 48 small colonies active. The consequence of this shift is the population as a whole becomes more at-risk in the event one or more

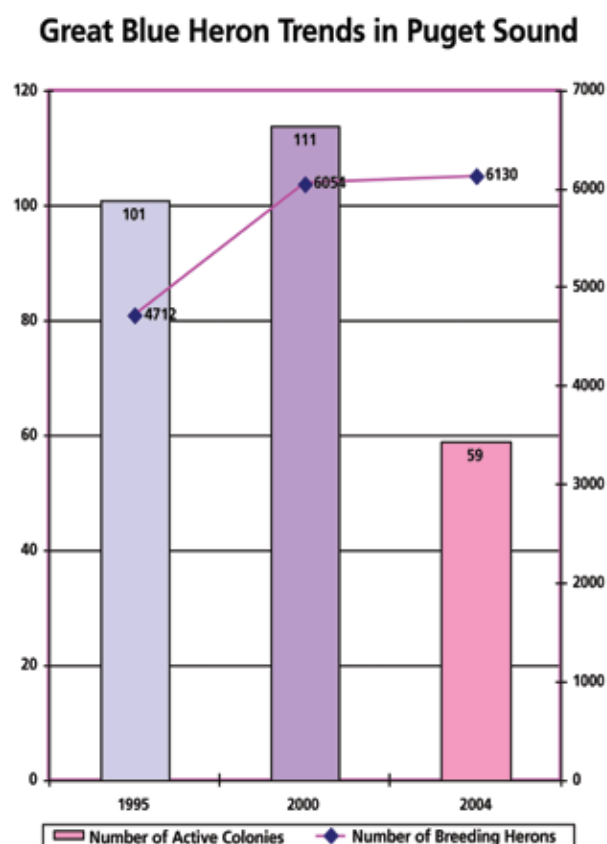


Figure 6. Puget Sound Population Trends.

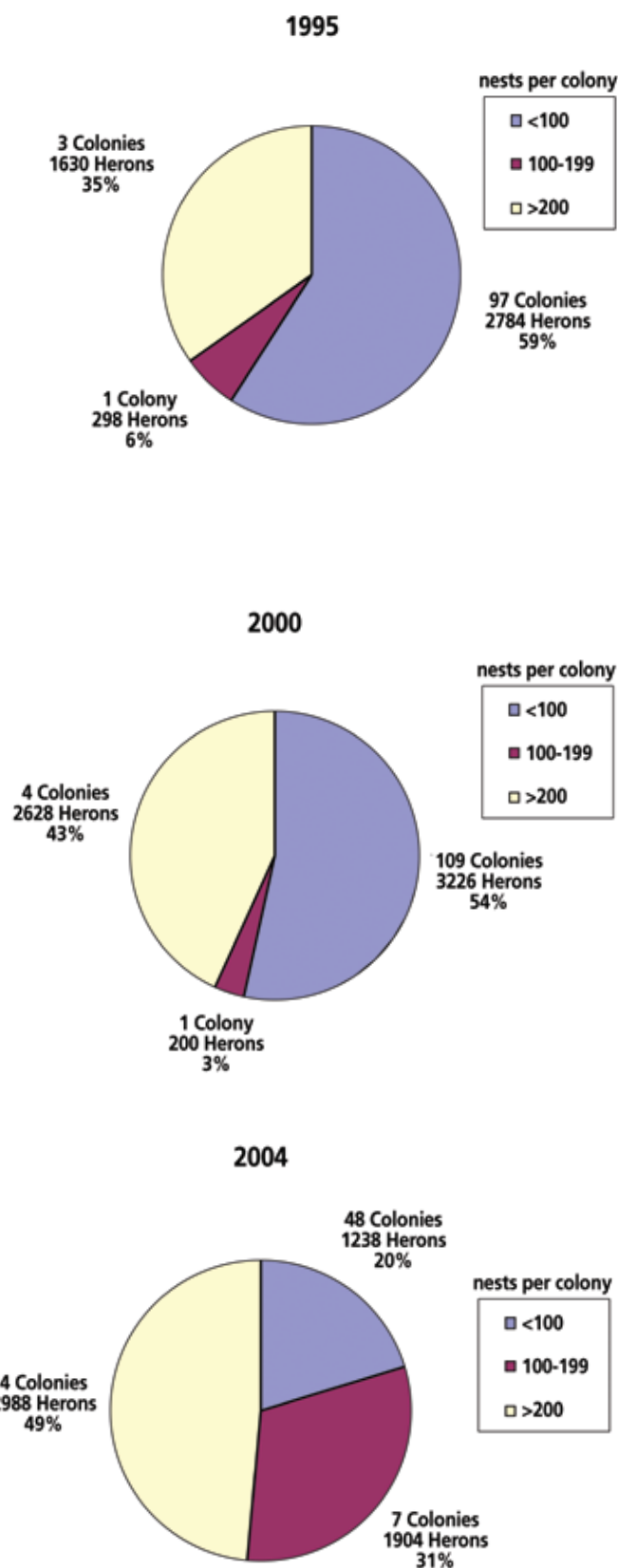


Figure 7. Puget Sound heron colony trends.

large colonies abandons or loses its productivity, even for a single season.

The consolidation of the Puget Sound heron population into large breeding centers needs to be assessed. Possible causal factors include combinations of increased predation by an expanding bald eagle population; human disturbance and encroachment on habitat due to amplified regional growth, development and land use impacting the nearshore; habitat alteration and loss, particularly fragmentation of nearshore - upland forests and loss of fallow fields; direct disturbance from low-flying aircraft; human activity including outdoor recreation and associated noise; pollution, particularly endocrine disruptors and persistent toxins; changes in prey species or distribution; and broad systemic changes or ecosystem decline. Effects of global warming also need consideration. Expansion of oxygen-depleted areas in Puget Sound could also have an impact on herons during the breeding season by reducing prey species.

Dynamics between heron colonies also contribute to breeding success and distribution. In review of heron colony data, there is evidence of yearly increases or decreases in nesting numbers at certain locations resulting from several potential sources including dislocation, abandonment and relocation, natural movement and return of young breeders to natal colonies. Sudden increases in nesting numbers are likely a result of an influx from fragmentation of a large colony nearby or abandonment of smaller colonies, with

the inverse causing decreases in colony size. Colonies sharing common foraging areas are likely to exchange breeding adults or absorb relocations (e.g., Davis Slough and Ault Field 2004, Point Roberts and Tsawwassen 2003 - 2004, Birch Bay and Lummi or Slater 1999, Chuckanut and Post Point 1999 - 2000) (WDFW database; Eissinger unpubl. data). Another potential natural trend is a long-term cycle with the expansion of large colonies as they assimilate small satellite colonies, followed by the fragmentation of the large colonies as they reach carrying capacity, creating smaller satellite colonies.

Currently, four colonies represent about 50 percent of the breeding population in the Salish Sea. Of these, the largest is located at March Point with an estimated 600 or more breeding pairs. This is followed by Tsawwassen (previously Point Roberts) with over 400 pairs, Birch Bay averaging 300 pairs and Samish Island with over 200 pairs. Large colony concentrations are important because fledging success is greater in larger colonies (Butler et al. 1995). Also, it is surmised that the influx of new herons to, and the dispersal of young from, these sites contributes significantly to the genetic diversity and health of the regional population (DesGranges 1988). The concentrated breeding centers create a high level of localized sensitivity and vulnerability, potentially placing regional populations at risk (E. Dunn et al., Long Point Bird Observatory, Port Rowan, Ontario, Canada).

Human Effects on Habitat Attributes

Populations of Great Blue Herons have fluctuated throughout their range over time. Along the eastern coast of North America during the late 1800s, hunters exploited herons for breeding plumes to decorate ladies' hats, lobstermen used herons as bait for lobster traps and fishermen targeted herons as competition for fish (Palmer 1949 in Gibbs et al. 1987). These activities nearly decimated the eastern population and affected populations of herons worldwide (del Hoyo et al. 1992). Few records of historical trends exist for the herons' western range. As the human population expanded, shoreline development enabled the transport of goods and services and resulted in growing settlements, towns and cities along coastlines and major waterways. It is this coastal expansion of human development that had the greatest historical impact on herons in the Pacific Northwest.

The human expansion continues. It is expected that the Puget Sound region will increase by 35 percent by 2020 (Transboundary George Basin - Puget Sound Environmental Indicators Working Group 2002). Pressures on the natural environment throughout Puget Sound are increasing with growth and infrastructure to support the human population. The primary human-related threats to the heron population and its fecundity include habitat loss, disturbance and toxins.

Habitat loss and fragmentation have the potential to greatly reduce foraging and nesting opportunities for Great Blue Heron throughout the Salish Sea. Conversion of coastal uplands, severing of the shoreline - upland interface and the infringement on shorelines by human development and recreational activities are increasing annually. Over one-third of Puget Sound's shoreline has been modified (WDNR 2006). Cumulative loss of suitable heron habitat has not been measured. However, habitat fragmentation has likely contributed to the consolidation and isolation of heron colonies. Isolation of heronries potentially increases their vulnerability to human disturbance and bald eagle predation, adversely affecting nesting productivity (Vennesland and Butler 2004). Conservation of nearshore habitat is difficult because 80 percent of the land within 1 kilometer of shoreline in Puget Sound is privately owned and contains desirable view property (Stinson et al. 2001).

Human disturbance of colonial nesting birds is well documented (Parnell et al. 1988) and is gaining consideration as a serious threat to the regional Great Blue Heron population (G. R. Vennesland, British Columbia Ministry of Water, Land and Air Protection, Surrey, unpubl. rep.; Murphy 1988, Eissinger 1996, Butler 1997, Stenberg 2001). In the Strait of Georgia, disturbance near breeding colonies has accounted for low productivity and nest failure (Vennesland and Butler 2004). Development and recreation-related disturbance to herons and their habitat has been cited in Puget Sound (Murphy 1988, Eissinger 1996, Stenberg 2001). Human disturbance may cause temporary or perma-

nent abandonment of a colony (Gebuer and Moul 2001). Residential and commercial developments have displaced nesting herons or infringed on buffers (Eissinger unpubl. data). Concentrated recreational activities along accessible shoreline areas impose disturbance in foraging areas with jet skis, boat wakes, pedestrians, hunting, fireworks and off-leash dogs (Eissinger pers. observ.). Shooting at herons and heron colonies is documented and in some cases is a result of increased road access (WDFW database; Murphy 1988). Lighting and increased traffic near one heron colony was implicated in its abandonment (John Erickson, Whidbey Naval Air Station, Oak Harbor, Washington, pers. comm.). Aerial disturbance by low-flying aircraft, primarily helicopters, has also been observed (Eissinger 2006).

The potential impact of a major oil spill on the regional heron population could be significant due to the close proximity of major breeding centers and foraging grounds to oil ports and refinery complexes. Five large heron colonies totaling 1,300 breeding pairs representing 42 percent of the entire Puget Sound breeding population are located within 6.4 km of shoreline crude oil off-loading ports and associated refineries. Three of the largest colonies and associated feeding areas are located directly adjacent to these facilities. In addition, ship traffic carrying and transporting petroleum products through the marine waters of Puget Sound also pose a risk for spills. Ship traffic is increasing, with an estimated 4,500 oil tankers and barges entering Puget Sound annually (Washington Department of Ecology [WDOE] 2006a).

Regulatory protection of heron colonies has failed to provide the necessary structure for protecting colonies and associated buffers without public or legal intervention. The Washington Shoreline Management Act encourages competing interests in shoreline areas and depends on local jurisdictions to protect ecological functions of shorelines while also providing for public access and appropriate development. Washington State Growth Management Act depends on local jurisdictions to designate heron colonies as critical areas or herons as species of local importance in order to regulate those locations. In most cases, local jurisdictions do not have a current inventory of colony sites or a protocol to locate or document colonies. WDFW provides excellent guidelines through their Priority Habitats and Species management recommendations, but rarely enforces infringements or imposes full protection of sites where development is proposed.

Conservation of heron colonies has had limited success. Over \$9 million of public and private funds have been spent in the past 10 years to purchase and protect eight heron colonies, many through combined corporate, government and community efforts. Additional in-kind donations of conservation easements and land have contributed to this conservation effort. Of the colonies protected, two have

been abandoned or relocated. However, the primary breeding centers lack full protection. Of the four mega-colonies representing half the breeding population, only one is fully protected with buffers, restricted access and consistent monitoring. Two partially protected colonies have limited or no buffers with occasional monitoring, and one remains unprotected and unmonitored. No foraging areas have been granted conservation status or restricted access.

Environmental Toxins

Certain environmental toxins impact human and wildlife populations with potential long-term consequences. Great Blue Herons supply biomagnified synthetic compound residues to their eggs, resulting in an excellent measure of locally derived environmental toxins (Whitehead et al. 1992, Harfenist et al. 1993, Wilson et al. 1996). With large concentrations of herons foraging in a localized fashion and using a variety of habitats including nearshore, wetlands and upland fields, these birds may accumulate and reflect toxins not exhibited in other species or sources.

The Canadian Wildlife Service began using Great Blue Heron eggs and tissue for toxicology sampling in the Strait of Georgia beginning in the mid 1970s. Over a period of nearly 30 years, these studies provided a means of determining temporal and geographic trends of organochlorine contamination within the study area of southwestern British Columbia. Between 1977 and 1993, Great Blue Heron eggs were collected from 23 colonies in the lower Fraser River. Chlorinated hydrocarbons were detected in all samples. Study results included sharp declines in organochlorine pesticides, including DDE (dichloro-diphenyl-dichloro-ethane), from the late 1970s, followed by little change (Elliott et al. 1989, Harris et al. 2003). The highest levels of most pesticides were associated with the Fraser River delta and were likely driven by estuarine processes and upstream land use (Harris et al. 2003). Another finding was a sharp decline in polychlorinated biphenyls (PCB) levels between 1977 and 1983 followed by a leveling of PCB concentrations. These data suggest an initial reduction of PCBs due to regulatory control, but later persistence from low-level input and atmospheric deposition (Wilson et al. 1996) particularly in urban areas (Harris et al. 2003).

Although current contaminant levels appear to be sub-lethal in adult herons, there are negative effects of certain compounds on eggshell thickness and reproductive success (Elliott et al. 1989). Great Blue Heron eggshells measured in British Columbia between 1977 and 1986 were consistently thinner than those measured before 1947, whereas eggshell thickness increased from 1987 to 1999 (Harris et al. 2003). Reproductive failure was documented where very high levels of dioxins were measured in eggs collected near a pulp mill (Elliot et al. 1989).

Measurements of contaminant levels from Great Blue Heron in Puget Sound are less comprehensive. Studies have been

limited to single seasons and restricted geographic coverage. Three published studies concentrated on organochlorine contaminant residues (Fitzner et al. 1988, Cobb et al. 1994, Cobb et al. 1995,) and one related eggshell thinning to organochlorine compounds (Speich et al. 1992). These studies showed elevated organochlorine contaminant levels in the central Puget Sound in the 1980s; however, there have been no subsequent studies to examine trends. Specific contaminants and toxin levels vary by region within Puget Sound, with higher levels measured in heron colonies near urban areas. No known baseline or long-term, heron-based toxicology monitoring has been conducted for the Puget Sound region. Currently, there are no studies in the Puget Sound utilizing herons as an indicator for environmental toxins (Gerald Hayes, WDFW, Olympia, pers. comm.). Parallels may be drawn from British Columbia studies for the Puget Sound where similar conditions exist. However, local contaminant baseline profiles and continued research throughout Puget Sound are needed.

Emerging Issues

Brominated fire retardants (BFRs) are widely used in a number of consumer products to prevent fire-related injury and property damage. Recently, it was shown that polybrominated diphenyl ethers (PBDEs), a type of BFR, are persistent in the environment and capable of accumulating in the tissues of animals, fish and humans (WDOE 2006b). Certain PBDEs also increase in toxicity as they are broken down and mimic vital hormones in mammals. These compounds require continued monitoring and study in both human and wildlife communities.

Wildlife-based PBDE sampling has been conducted in Washington and British Columbia. Great Blue Heron eggs were tested in the Fraser River estuary by the Canadian Wildlife Service between 1983 and 2002 (Elliott et al. 2005) and showed an exponential increase of PBDEs (doubling time 5.7 years) with the highest value measured in 2002. This type of ongoing monitoring is important in tracking environmental PBDEs as they relate to the human population and to local marine and estuarine food chains (Elliott et al. 2003).

Infectious diseases such as West Nile virus and avian influenza, most notably the H5N1 virus, have been detected in herons (*Ardea* sp.) (Guan et al. 2004), yet the effect of these pathogens on Great Blue Heron populations specifically is not known. West Nile virus has been reported infecting birds throughout most of the United States including eastern Washington, but no positive avian infections have been reported in Puget Sound. Avian influenzas of many different strains occur naturally in wild birds, particularly waterfowl and shorebirds (Trapp 2005) but rarely cause mortality. Monitoring of avian flu and West Nile virus in certain North American colonial bird populations, including Great Blue Heron, may be useful as an indicator.

Ecosystem Processes Supporting Habitat Attributes

The Great Blue Heron serves as a valued ecosystem component (VEC) of the Puget Sound nearshore by linking a variety of habitats from the marine intertidal, shoreline and aquatic systems to the upland. Herons also serve as an indicator of environmental health and ecological function throughout the Salish Sea coastal region.

The Great Blue Heron is linked with every VEC during its life cycle. These linkages form an interconnected web that illustrates the complexity and interdependence of the near-shore process and function. The habitat matrix on which the heron depends is diverse and changeable both spatially and temporally. This matrix includes marine, estuarine, freshwater, riparian and upland systems, providing the associated prey species and habitat conditions necessary to meet the needs of herons either seasonally or year-round.

The VEC Model (Figure 8) for Great Blue Heron is based on several considerations and actions that depend on a broader understanding of the heron's life cycle, prey base and habitat relationships. The VEC table (Appendix B) provides the basis on which the model was crafted by detailing necessary data and actions. Management and restoration priorities depend on the filling of data gaps, ongoing monitoring of both individual colonies and the population as a whole. The model serves to illustrate the complex interrelationship of the heron with the nearshore and its suitability as an indicator species.

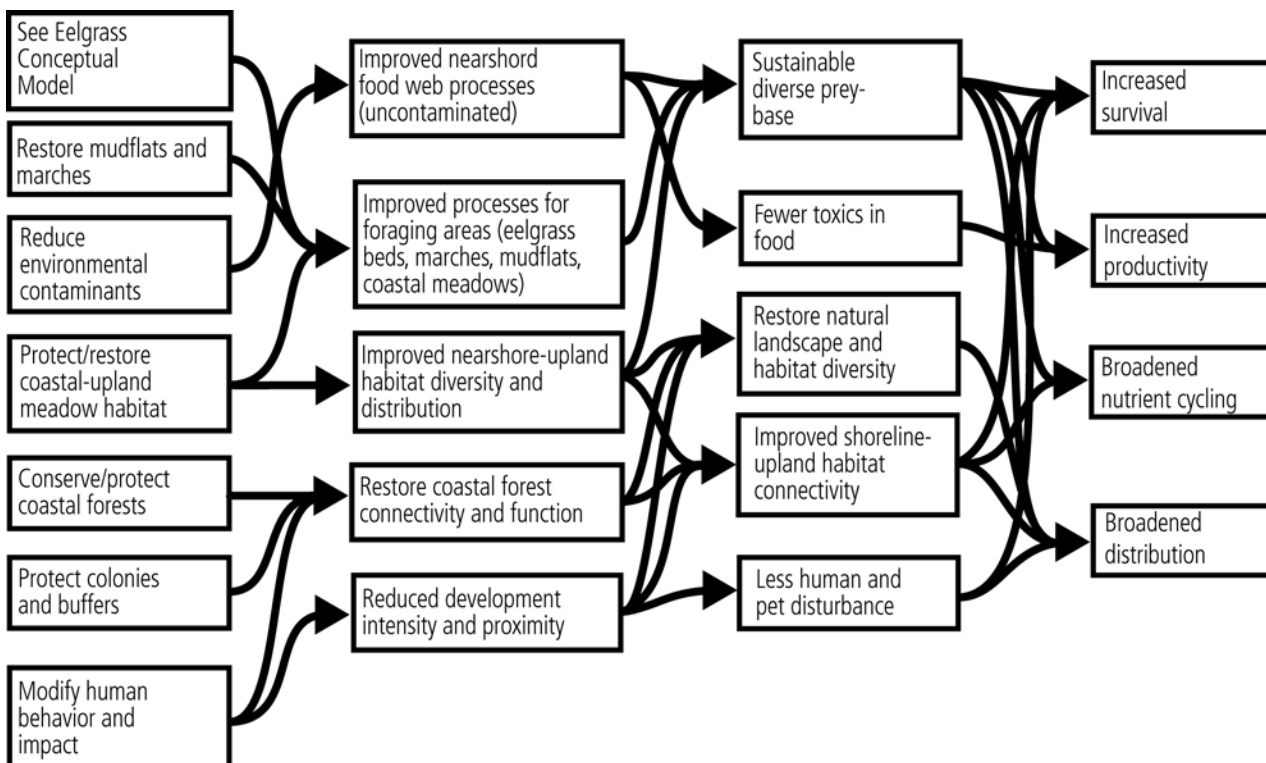


Figure 8. VEC model.

Informational Gaps and Critical Uncertainties

The Great Blue Heron, for all its iconic value and broad distribution in Puget Sound, is yet poorly studied. Population fluctuations, colony abandonment, prey selection and abundance, toxic load and response to stressors are all areas of limited knowledge and understanding. In preparation of this paper, agencies, researchers, data specialists, field biologists and the Heron Working Group were contacted in order to obtain the best available science related to the Great Blue Heron. During the review of data, reports and published literature, gaps in the information were encountered. These gaps and uncertainties are numerous.

The regional heron population is dependent on a complexity of habitat, prey and seasonal associations. Recent consolidation of the breeding population and loss of smaller colonies indicate changes in the environment that are not well understood. Although the breeding population is relatively easy to track, we know much less about foraging, seasonal dispersal, range, winter distribution and habitat associations.

Population monitoring and tracking begins with the breeding centers. Annual monitoring of heron colonies, associated habitats and foraging areas is essential in order to understand population dynamics, productivity, site-specific conditions and stressors, and to document failures and abandonment. To date, few colonies are monitored annually and even fewer throughout the breeding season. Detailed colony profiles including history and trends are lacking for most colonies. With inconsistencies in colony data, regional assessments and trends are difficult to determine, including inter-colony exchange, interaction and cycles. Stressors, such as bald eagle predation, human encroachment or aerial disturbance also need to be documented since they will vary by colony. Standard methodologies are needed in order to produce useful, comparable data.

Nearshore prey species, abundance, seasonality and distribution are not documented for Puget Sound. Multi-seasonal survey data for foraging areas is lacking. Regular foraging data collection, particularly in association with breeding colonies, is needed to track changes and correlate food supply with colony productivity. Site-specific baselines in major concentration areas would be beneficial for future comparisons and damage assessment in the event of an oil spill or other calamity.

Heron distribution and habitat utilization on different spatial and temporal scales in Puget Sound has yet to be studied. While the limited research has been centered on breeding activities and associated colonies, documentation and supporting empirical data related to fledgling dispersal, seasonal distribution and habitat associations in general do not exist. Numerical occurrence data outside the breeding period are limited to Christmas Bird Count circles and unpublished accounts.

Habitat loss and displacement of herons due to human development and increased recreational activity in coastal regions of Puget Sound has not been measured. Alternate habitat and habitat reserves have not been identified. Placement, design and construction of roads, buildings and other facilities need consideration near heron concentration areas and in heron flyways.

Accounts of disturbance to herons and heron colonies in Puget Sound are chiefly anecdotal. Research aimed at defining disturbance is also difficult owing to the unique characteristics of each colony, roost or foraging area. Therefore, disturbance studies need to be site-specific. Documentation of the types of disturbance, timing, sensitivity and response is needed. Disturbance data collection could also be integrated into site monitoring.

Tracking toxins in the Puget Sound environment by utilizing Great Blue Herons would be useful as a measure of ecosystem health. Herons provide a unique toxin profile that includes multiple local sources. This type of toxicology data is lacking in Puget Sound. The contaminant load in the heron population could also affect reproduction and fitness. No testing for avian-related pathogens or parasites has occurred in or out of heron colonies within the region.

Nutrient transfer between the nearshore and upland by herons has not been quantified. The short- and long-term effect of this transfer into nest colonies and other uplands is likely a vital component of coastal forest ecology. Testing of soils, tracking of vegetation changes and intra-stand movement of colonies would be useful to determine the importance of this function.

Protection of heron colonies and associated habitats is needed in order to maintain the present heron population in Puget Sound. Conservation of major breeding colonies with adequate buffers and timing restrictions is essential since 80 percent of the breeding population is located in only 11 sites, few of which are fully protected. Associated supporting habitats and foraging areas also require protection. Conservation needs to interface with state and local jurisdictional processes. Finally, a formal heron conservation initiative is needed to guide the process and provide collaborative stewardship opportunities, perform monitoring and seek funding for habitat acquisition and other conservation mechanisms.

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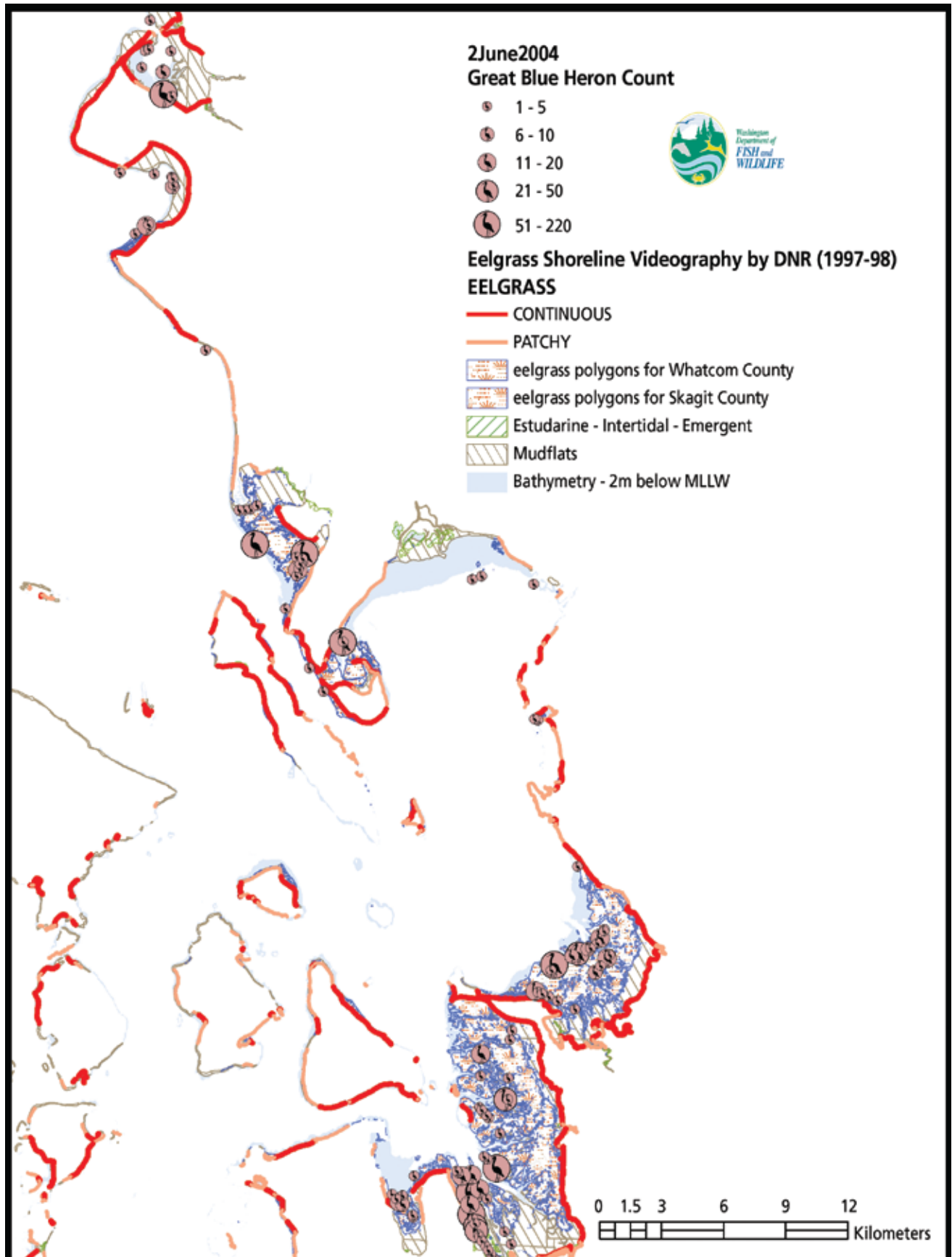
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Data Sources

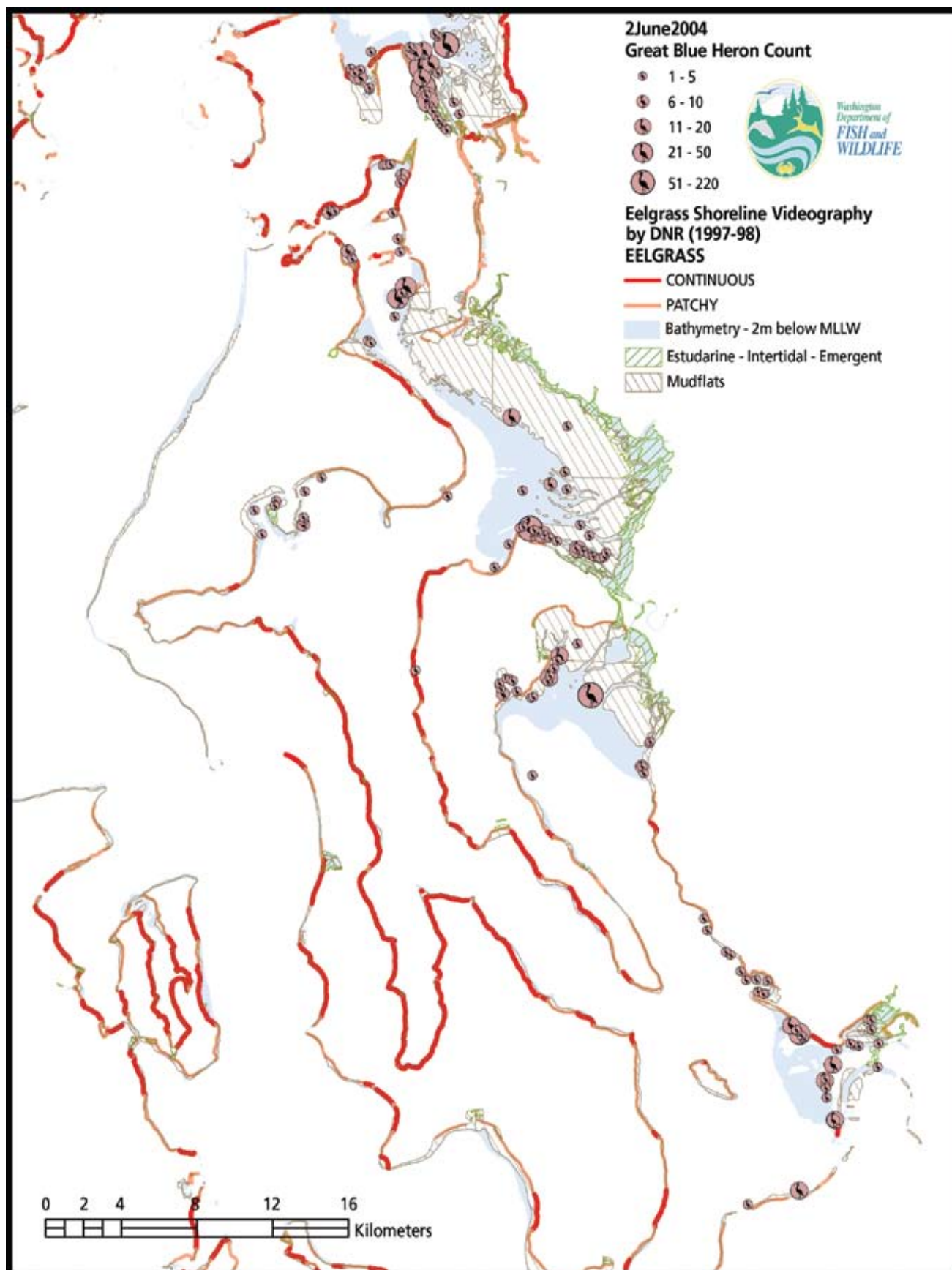
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Appendix A: Great Blue Heron Foraging Distribution 2004

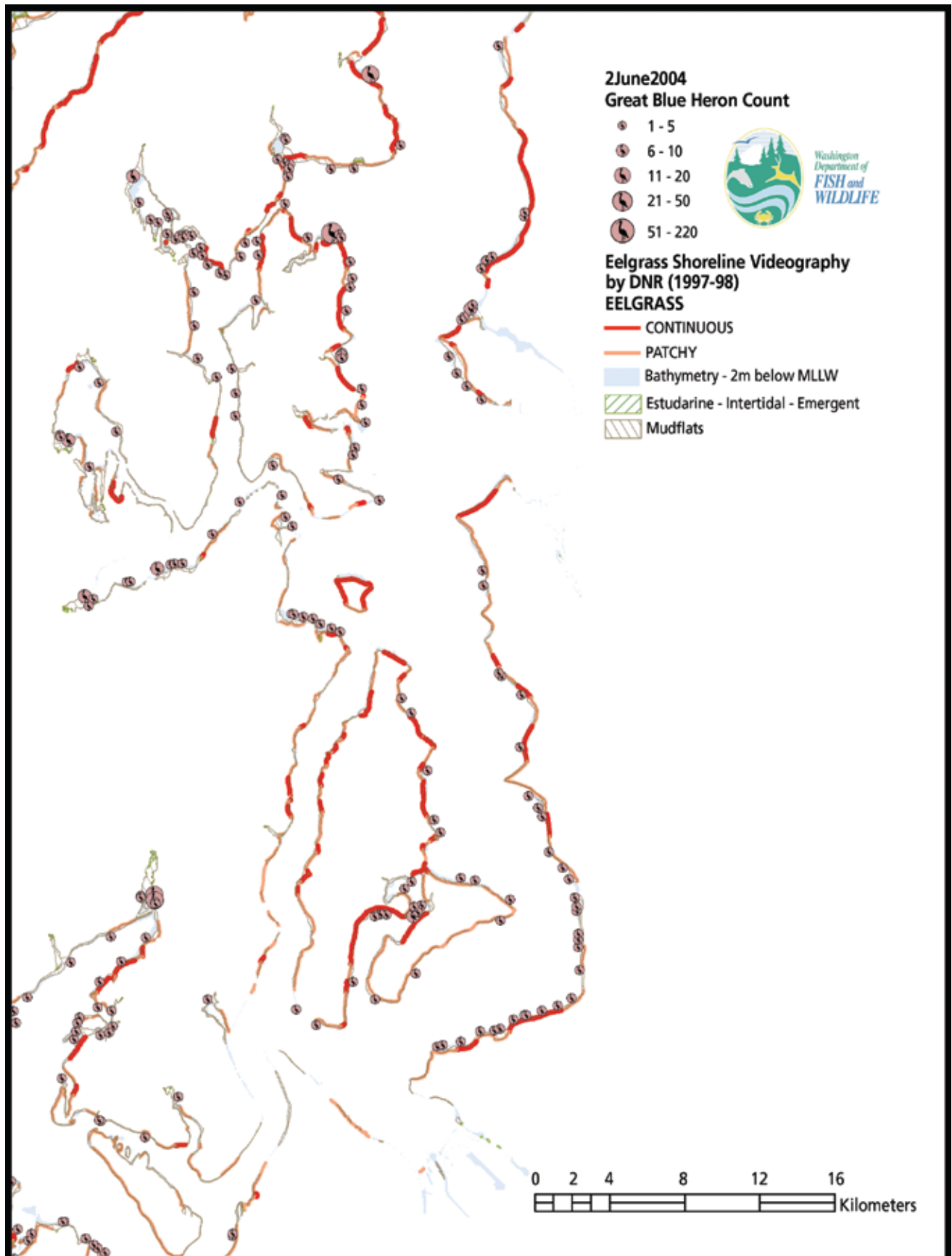
Drayton Harbor to Padilla Bay



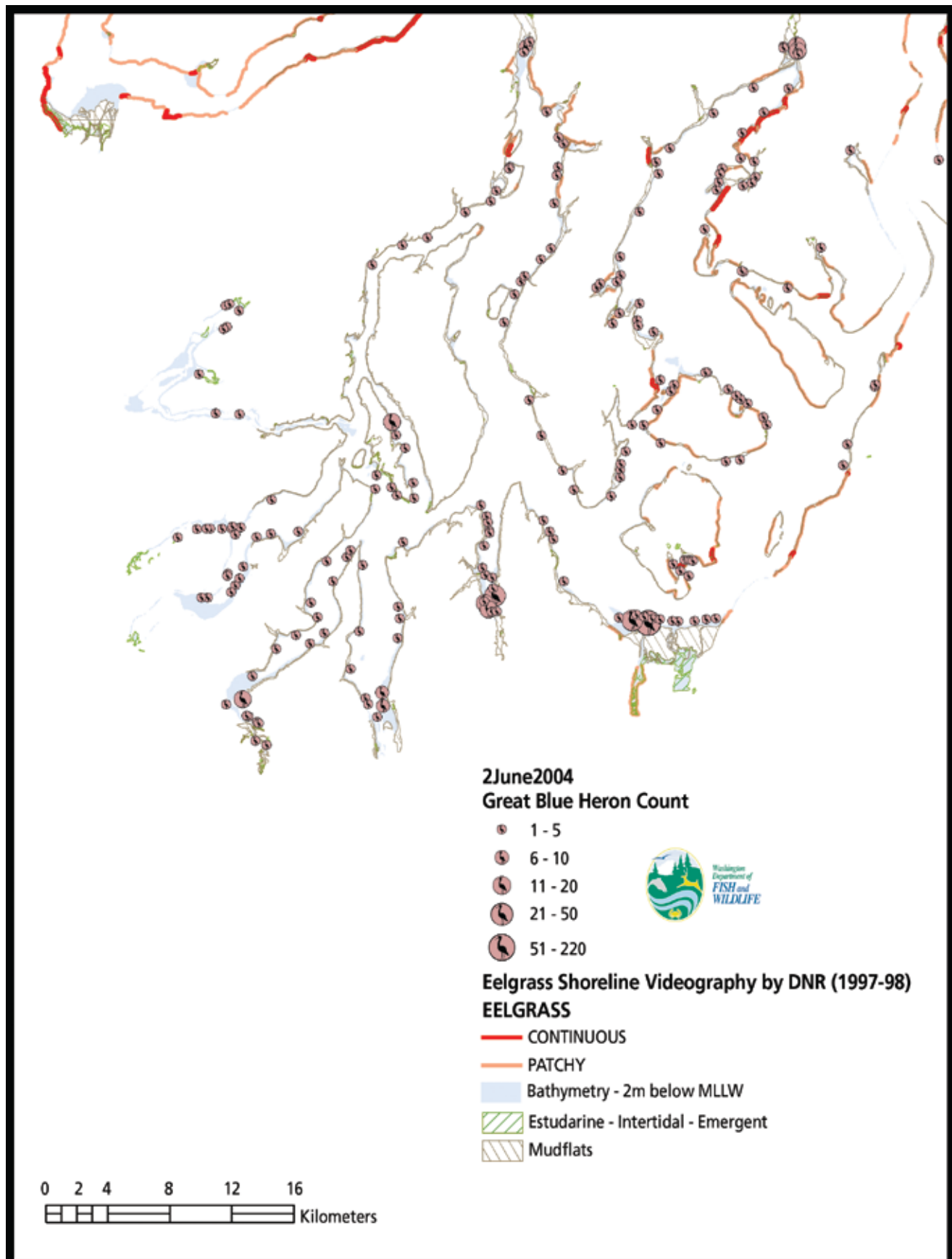
Skagit Bay to Possession Sound



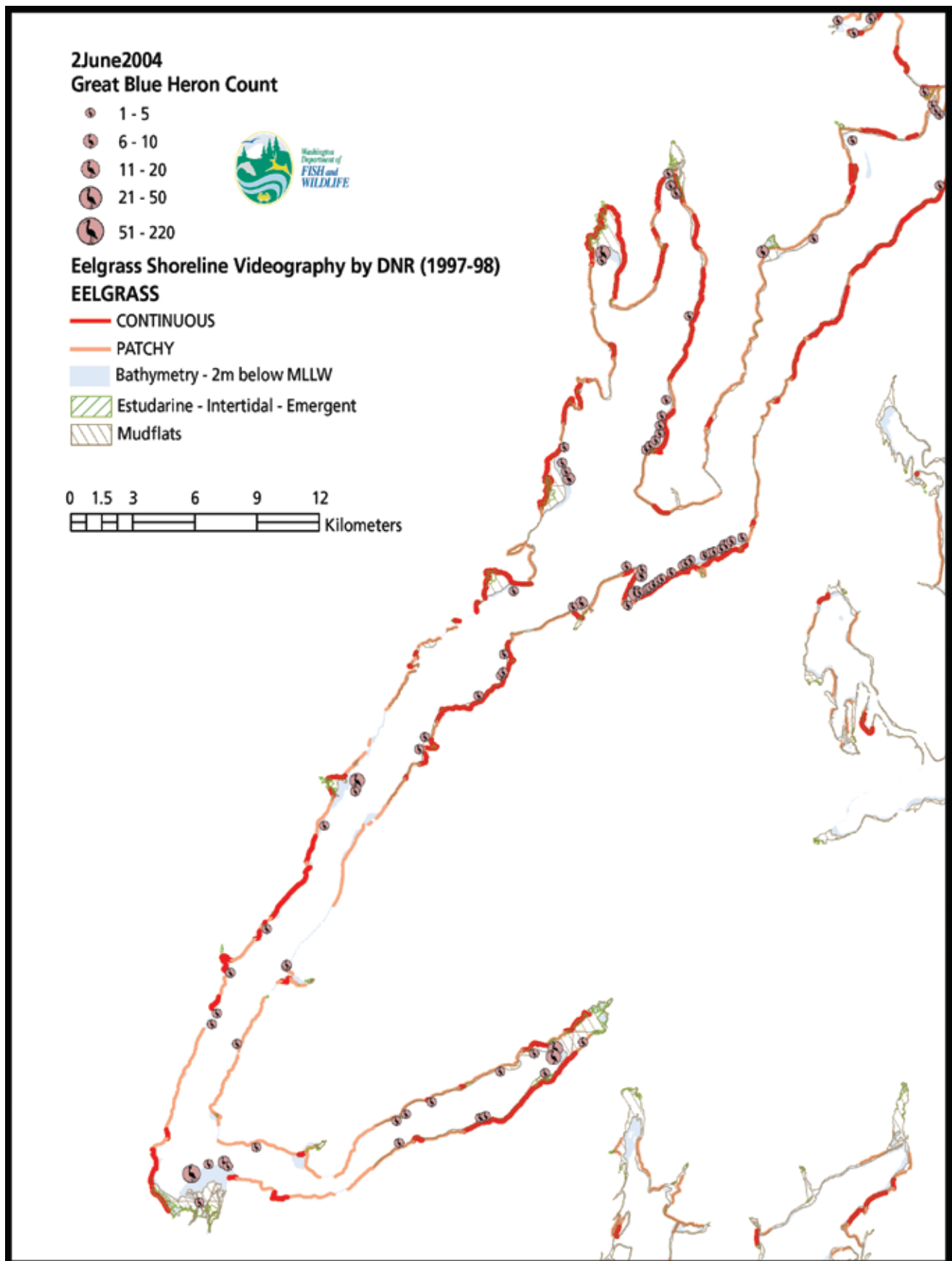
Possession Sound to Commencement Bay



South Puget Sound



Hood Canal



Attachment B

Great Blue Heron VEC Model: Table of Considerations

Data Needed	Management Measure	Restored Nearshore Processes	Structural Changes	Functional Response
Identify colony sites	Protect colonies and contiguous forest stands and buffers	Increase nesting area habitat attributes	Stabilize colony function and productivity	Improve site fidelity and productivity over time
Identify supporting heron-habitat matrix + define matrix and build habitat profile for each colony	Protect primary habitat components for each colony	Improve food web processes and exchange between all habitats	Stabilize colony function and productivity and improve habitat connectivity	Improve site fidelity and productivity over time
Identify primary near-shore components and interface with upland	Protect nearshore-upland habitat linkages	Improved faunal flow and nutrient exchange between nearshore and upland	Restore natural landscapes and connectivity, diversify habitat opportunities	Increased biodiversity of nearshore and associated biological communities
Identify primary foraging concentration areas and associated prey	Protect foraging habitats and prey species through full life cycle	Improve foraging habitat processes and prey-base life cycles	Sustainable prey-base and habitats under various conditions and seasons	Increase productivity, colony success and survival
Identify potential nesting areas	Protect diverse contiguous coastal forest stands	Improved fauna flow and nutrient exchange between nearshore to upland	Improve nesting opportunities	Broaden breeding distribution
Identify human disturbance	Limit access, recreation and reduce development and sprawl	Improved fauna flow, habitat function and connectivity	Reduced human related interference, disruption and pollution	Broaden distribution and improve feeding and nesting success
Identify toxic input	Reduce contaminants in water, sediment transfer and prey	Improve water quality and food web	Reduced endocrine disruption and toxic side effects	Healthier ecosystem

PSNERP and the Nearshore Partnership

The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) was formally initiated as a General Investigation (GI) Feasibility Study in September 2001 through a cost-share agreement between the U.S. Army Corps of Engineers and the State of Washington, represented by the Washington Department of Fish and Wildlife. This agreement describes our joint interests and responsibilities to complete a feasibility study to

“...evaluate significant ecosystem degradation in the Puget Sound Basin; to formulate, evaluate, and screen potential solutions to these problems; and to recommend a series of actions and projects that have a federal interest and are supported by a local entity willing to provide the necessary items of local cooperation.”

The current Work Plan describing our approach to completing this study can be found at:

<http://pugetsoundnearshore.org/documents/StrategicWork-Planfinal.pdf>

Since that time, PSNERP has attracted considerable attention and support from a diverse group of individuals and organizations interested and involved in improving the health of Puget Sound nearshore ecosystems and the biological, cultural, and economic resources they support. The **Puget Sound Nearshore Partnership** is the name we have chosen to describe this growing and diverse group, and the work we will collectively undertake that ultimately supports the goals of PSNERP, but is beyond the scope of the GI Study. Collaborating with the Puget Sound Action Team, the Nearshore Partnership seeks to implement portions of their Work Plan pertaining to nearshore habitat restoration issues. We understand that the mission of PSNERP remains at the core of our partnership. However, restoration projects, information transfer, scientific studies, and other activities can and should occur to advance our understanding and, ultimately, the health of the Puget Sound nearshore beyond the original focus and scope of the ongoing GI Study.

As of the date of publication for this Technical Report, our partnership includes participation by the following entities:

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|---|--------------------------------------|--|--|
| • King Conservation District | • Pierce County | • U.S. Department of Energy | • Washington Department of Fish and Wildlife |
| • King County | • Puget Sound Partnership | • U.S. Environmental Protection Agency | • Washington Department of Natural Resources |
| • National Wildlife Federation | • Recreation and Conservation Office | • U.S. Geological Survey | • Washington Public Ports Association |
| • NOAA Fisheries | • Salmon Recovery Funding Board | • U.S. Fish and Wildlife Service | • Washington Sea Grant |
| • NOAA Restoration Center | • Taylor Shellfish Company | • U.S. Navy | • WRIA 9 |
| • Northwest Indian Fisheries Commission | • The Nature Conservancy | • University of Washington | |
| • Northwest Straits Commission | • U.S. Army Corps of Engineers | • Washington Department of Ecology | |
| • People for Puget Sound | | | |

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PUGET SOUND NEARSHORE PARTNERSHIP



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